DESCHUTES BASIN
HABITAT CONSERVATION PLAN

STUDY REPORT

Study 14: Assessment of Fish Passage and Screening at Diversions Covered by the DBHCP – Phase 1

Prepared for:

Deschutes Basin Board of Control, and
City of Prineville, Oregon

Prepared by:

Biota Pacific Environmental Sciences, Inc.
And
R2 Resource Consultants, Inc.

March 2013

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Acronym, Symbol, Abbreviation	Definition
@	At
Ac-Ft	Acre-feet
AID	Arnold Irrigation District
Alt	Alternative
Approx.	Approximate
AV	Approach Velocity (fps)
Bdg	Bridge
BFW	Bank Full Width
BLM	United States Bureau of Land Management
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
BPA	Bonneville Power Administration
ºC	Degrees Celsius
CCI	Construction Cost Index
CFR	Code of Federal Regulations
Cfs	Cubic feet per second
Cm	Centimeter
COCO	Central Oregon Cities Organization
COIC	Central Oregon Intergovernmental Council
COID	Central Oregon Irrigation District
Cr	Creek
CREP	Conservation Reserve Enhancement Program
CRWC	Crooked River Watershed Council
CTWS	Confederated Tribes of Warm Springs
Cu Ft	Cubic Feet
CWA	Clean Water Act
DBBC	Deschutes Basin Board of Control
DBHCP	Deschutes Basin Habitat Conservation Plan
DEQ	Oregon Department of Environmental Quality
DO	Dissolved oxygen
DRC	Deschutes River Conservancy
DWA	Deschutes Water Alliance
$	Dollar
DN	Downstream Passage Alternative
d/s	Downstream
Ecology	Washington State Department of Ecology
EF	East Fork
EL.	Elevation
ENR	Engineering News Record
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
et al.	And others
etc.	et cetera; and so on
ºF	Degrees Fahrenheit
f/m^2	Fish per square meter

Acronym, Symbol, Abbreviation	Definition
FERC	Federal Energy Regulatory Agency
FS	Forest Service
FSC	Floating Surface Collector
‘	Foot
Ft	Feet
Ft^2	Square Feet
FTE	Full Time Equivalent
fps	Feet per second
gal	Gallon
GIS	Geographic Information Systems
GBD	Gas Bubble Disease
GBT	Gas Bubble Trauma
gpm	Gallons per minute
>	Greater than
GW	Groundwater
HDQrs	Headquarters
HCP	Habitat Conservation Plan
Hwy	Highway
“	Inch
I.D.	Inside Diameter
kg	Kilogram
kWh	Kilowatt-hour
LASAR	Laboratory Analytical Storage and Retrieval Database
Lb	Pound
<	Less than
M	Meter
m^2	Square Meter
Mm	Millimeter
max	Maximum
Mg	Milligram
mg/L	Milligrams/liter
Min	Minimum
MLCO	Mill Creek nr Schoolhouse; Hydromet Gauge #14083400 code
MP	Mile Post
mpg	Miles per gallon
MSL	Mean Sea Level
N	North
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NUID	North Unit Irrigation District
O & M	Operation and Maintenance
0+ age	Juvenile fish – less than a year in age
OAR	Oregon Administrative Rule
OCRO	Ochoco Creek blw Marks Creek; Hydromet Gauge #14082550 code
OCHO	Ochoco Creek blw Reservoir; Hydromet Gauge #14085300 code

Acronym, Symbol, Abbreviation	Definition
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ODOT	Oregon Department of Transportation
OID	Ochoco Irrigation District
OSU	Oregon State University
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Department of Water Resources
%	Percent
P	Probability
Pers. Comm.	Personal Communication
PGE	Portland General Electric
POD	Point-of-Diversion
PSE	Puget Sound Energy
Q	Discharge (cfs)
R.	River
R^2	Coefficient of Determination; Square of the Correlation Coefficient
r^2	Coefficient of Determination; Square of the Correlation Coefficient
R2	R2 Resource Consultants, Inc.
RBT	Rainbow Trout
Rd	Road
Reclamation	United State Bureau of Reclamation
Res.	Reservoir
RM	River Mile
§	Section
SA	Surface Area (ft^2)
SA_e	Effective Surface Area (ft^2)
SC	Screen Contact
SID	Swalley Irrigation District
SOP	Standard Operating Procedure
STH	Steelhead Trout
SWCD	Soil and Water Conservation District
TDG	Total Dissolved Gas
TID	Tumalo Irrigation District
TMDL	Total Maximum Daily Load
TSID	Three Sisters Irrigation District
TSS	Total Suspended Solids
UDWC	Upper Deschutes Watershed Council
Ug	Microgram
UGB	Urban Growth Boundary
UP	Upstream Passage Alternative
US	United States
USACOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USBR	United State Bureau of Reclamation
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Acronym, Symbol, Abbreviation	Definition
u/s	Upstream
w/	With
WF	West Fork
Ww	Wetted width
WWTP	Wastewater Treatment Plant
Yr	Year
Z	Depth

1.0 Introduction

1.1. Background

Seven central Oregon irrigation districts (Arnold, Central Oregon, North Unit, Ochoco, Swalley, Three Sisters, and Tumalo) and the City of Prineville, Oregon (City) are seeking Federal Endangered Species Act (ESA) incidental take permits for the bull trout (*Salvelinus confluentus*), Middle Columbia River steelhead (*Oncorhynchus mykiss*), Middle Columbia River spring Chinook salmon (*O. tshawytscha*), Deschutes River summer/fall Chinook salmon, Sockeye salmon (*O. nerka)*, and up to 10 other unlisted species inhabiting the Deschutes River basin. As required by Section 10 of the ESA, the City and the irrigation districts (collectively the Applicants) are preparing the Deschutes Basin Multi-species Habitat Conservation Plan (DBHCP) to minimize and mitigate the effects of the proposed incidental take on the covered species. The DBHCP is being prepared in cooperation with a multi-stakeholder Working Group representing the US Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), US Bureau of Reclamation (Reclamation), US Bureau of Land Management (BLM), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), Oregon Water Resources Department (OWRD), the Confederated Tribes of the Warm Springs, Crook County, and several non-governmental entities.

This study has been completed to support development of the DBHCP. The scope of work for the study was reviewed and approved by the Working Group prior to initiation. Drafts of this report are being provided to the Working Group for review and comment, and the final report will reflect their input.

1.2. Purpose, Scope and Methods

The purpose of this study is to document current conditions with respect to fish passage and fish screens at all surface water points of diversion covered by the DBHCP. The passage and screening provisions at the points of diversion are evaluated for their adequacy to protect covered fish species, where the diversions occur in waters currently occupied or potentially occupied by the covered fish species. Unless otherwise stated, all statements of fish presence or potential presence in individual covered waters were derived from StreamNet (2012). This study does not address possible effects to the Oregon spotted frog. These effects are currently under discussion with the USFWS, and will be addressed in subsequent study reports.

Evaluations of passage structures and screens prepared by ODFW, USFWS, NMFS, and others were utilized whenever available. Evaluations by ODFW generally refer to conformance with "state criteria" and "criteria for resident trout," but according to ODFW (2012a) these state standards are consistent with current NMFS (2011) criteria and should be considered equivalent. Where available, screen evaluation data were compared to the NMFS (2011) screening criteria. If previous evaluations were not available, points of diversion were evaluated based on reported design and operation data (particularly in the case of unscreened pump intakes) or site visits by fish passage and intake screening experts.

It is anticipated the information provided in this report will be used to identify and prioritize covered points of diversion for new or upgraded fish passage and/or screening to protect covered species. Part of the future prioritization will be site-specific assessment of costs and benefits that consider physical and operational constraints at each point of diversion, as well as anticipated benefits to covered species. Once the need for a passage structure or screen is identified, a site-specific design and cost estimate can be prepared to support DBHCP development discussions.

2.0 Results

2.1. Overview

Over 140 points of diversion will be covered by the Deschutes Basin HCP (Figure 2-1 through Figure 2-6). These diversions include 38 in the Deschutes River, one in Tumalo Creek, two in Crater Creek/Little Crater Creek, one in Whychus Creek, 36 in the Crooked River, 39 in Ochoco Creek, five in McKay Creek, and multiple locations in Johnson, Dry, and Lytle creeks.

Most (99) of the covered points of diversion are small pumps or gravity diversions operated directly by individual irrigation district patrons. None of these patron diversions obstructs fish movement. Most have maximum diversion rates of less than 1.0 cfs, and 41 of the pumps (29%) divert less than 0.1 cfs. Only five of the patron pumps are known to have capacities greater than 1.0 cfs. Few of the intakes for these diversions are currently screened to exclude fish.

Another three points of diversion are pumps operated directly by the irrigation districts. The largest of these diversions is the Crooked River Pumping Plant operated by North Unit Irrigation District (NUID). The other two are subsurface riparian pumps on Ochoco Creek (North and South Infiltration Galleries) operated by Ochoco Irrigation District (OID). The Crooked River Pumping Plant is screened. The other two pumps have subsurface intakes that do not entrain fish or interfere with fish passage.

Thirty-four of the points of diversion (POD) involve gravity flow into irrigation district canals. These diversions range in size from very small intakes on seasonal creeks to the principal irrigation district diversions on the major rivers and streams in the basin. Fewer than half (15 of 34) of the PODs divert water from perennial streams, while another 17 PODs divert from small, seasonal streams. Two diversions are currently inactive. Screening and passage at these facilities are variable, as discussed below for each diversion, by drainage basin.

Forty-one of the covered points of diversion occur in the Deschutes River or its tributaries above Big Falls, and are therefore outside the area accessible to reintroduced steelhead trout and salmon. Bull trout occurred historically in the Upper Deschutes Basin, but they are currently considered extirpated above Big Falls (Buchanan et al. 1997) except for an isolated population in Odell Lake and Odell Creek at the extreme upper (southern) end of the basin. The Odell Lake basin is upstream of the DBHCP covered lands and zone of the potential influence of covered activities. There are currently no formal plans to reintroduce bull trout above Big Falls. A number of the covered points of diversion above Big Falls have been evaluated for resident fish passage and screening by ODFW, applying criteria comparable to those used by NMFS (2011) for anadromous fish. Although they do not have the potential to entrain or block the movement of fish covered by the DBHCP, the screens are addressed briefly in this report for general information.

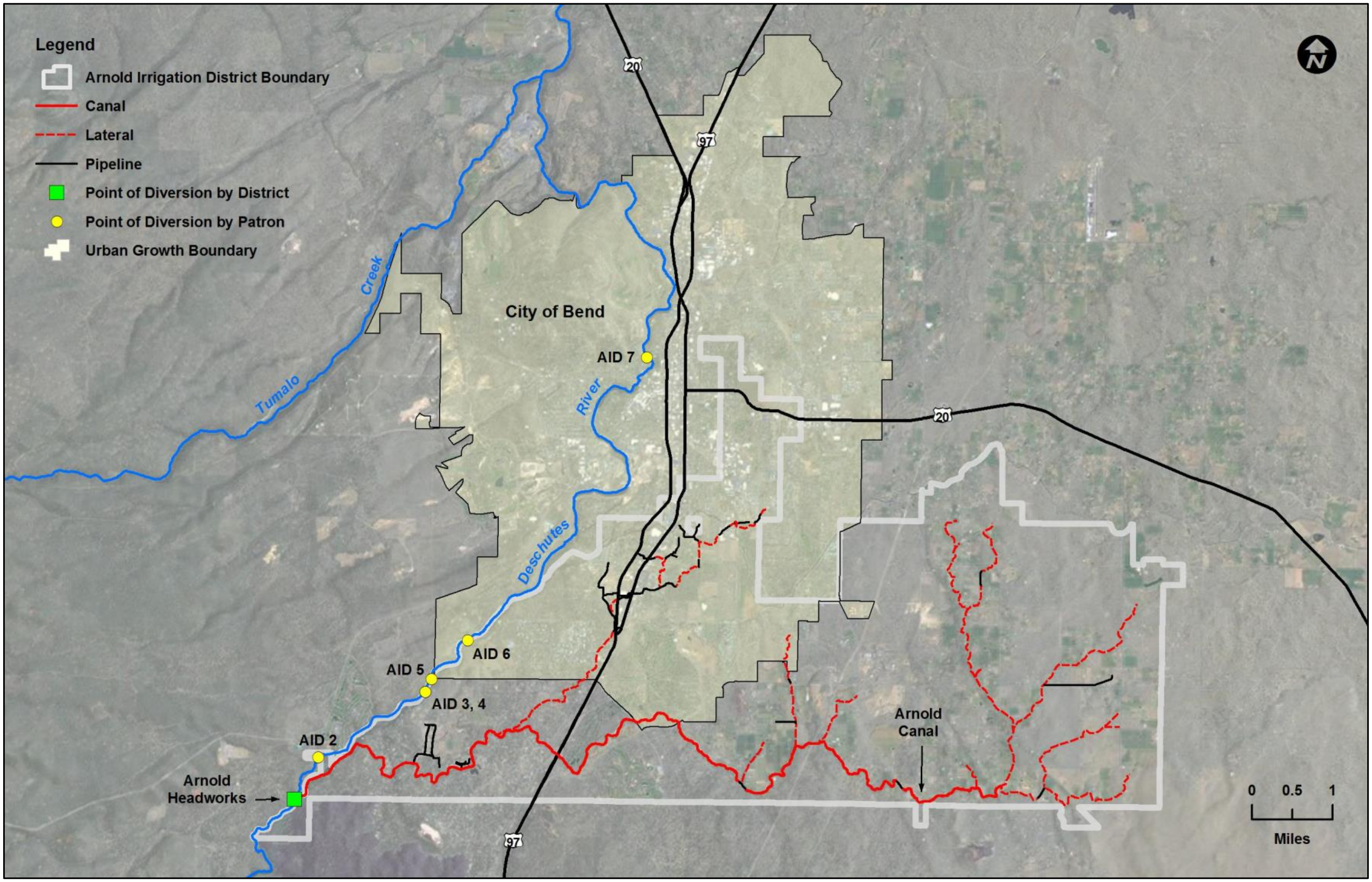

Figure 2-1. Map of Arnold Irrigation District showing authorized points of diversion.

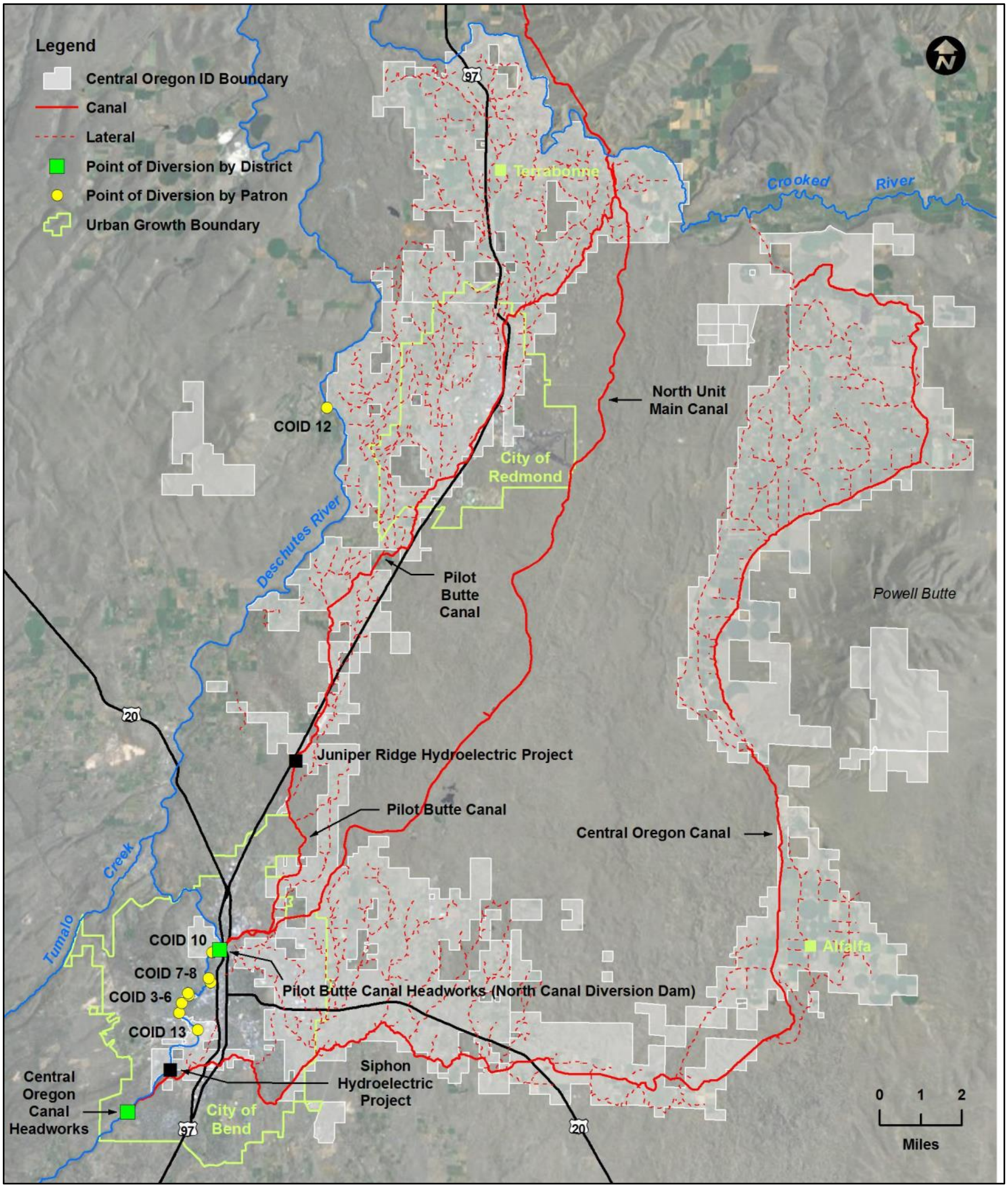

Figure 2-2. Map of Central Oregon Irrigation District showing authorized points of diversion.

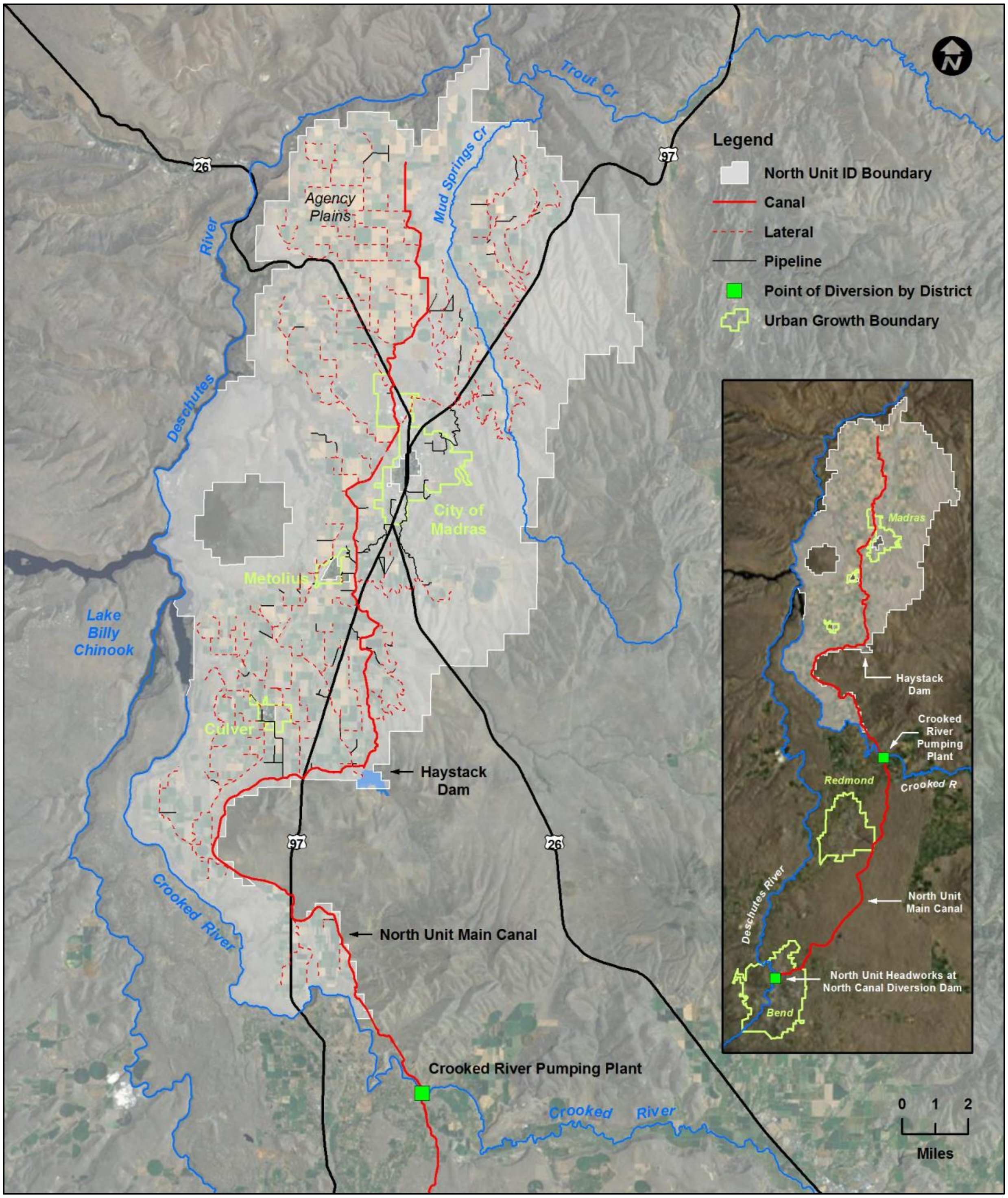

Figure 2-3. Map of North Unit Irrigation District showing authorized points of diversion.

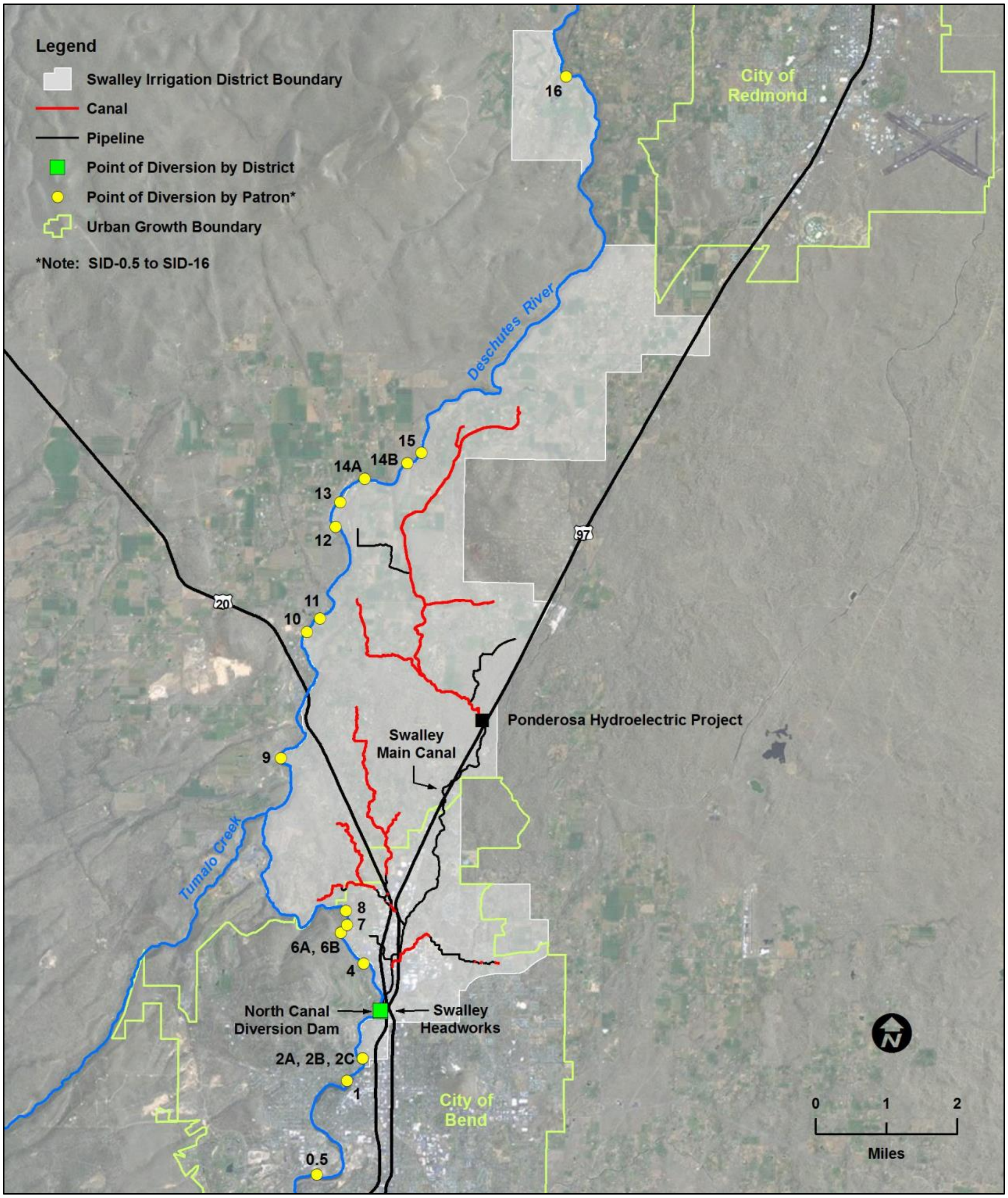

Figure 2-4. Map of Swalley Irrigation District showing authorized points of diversion.

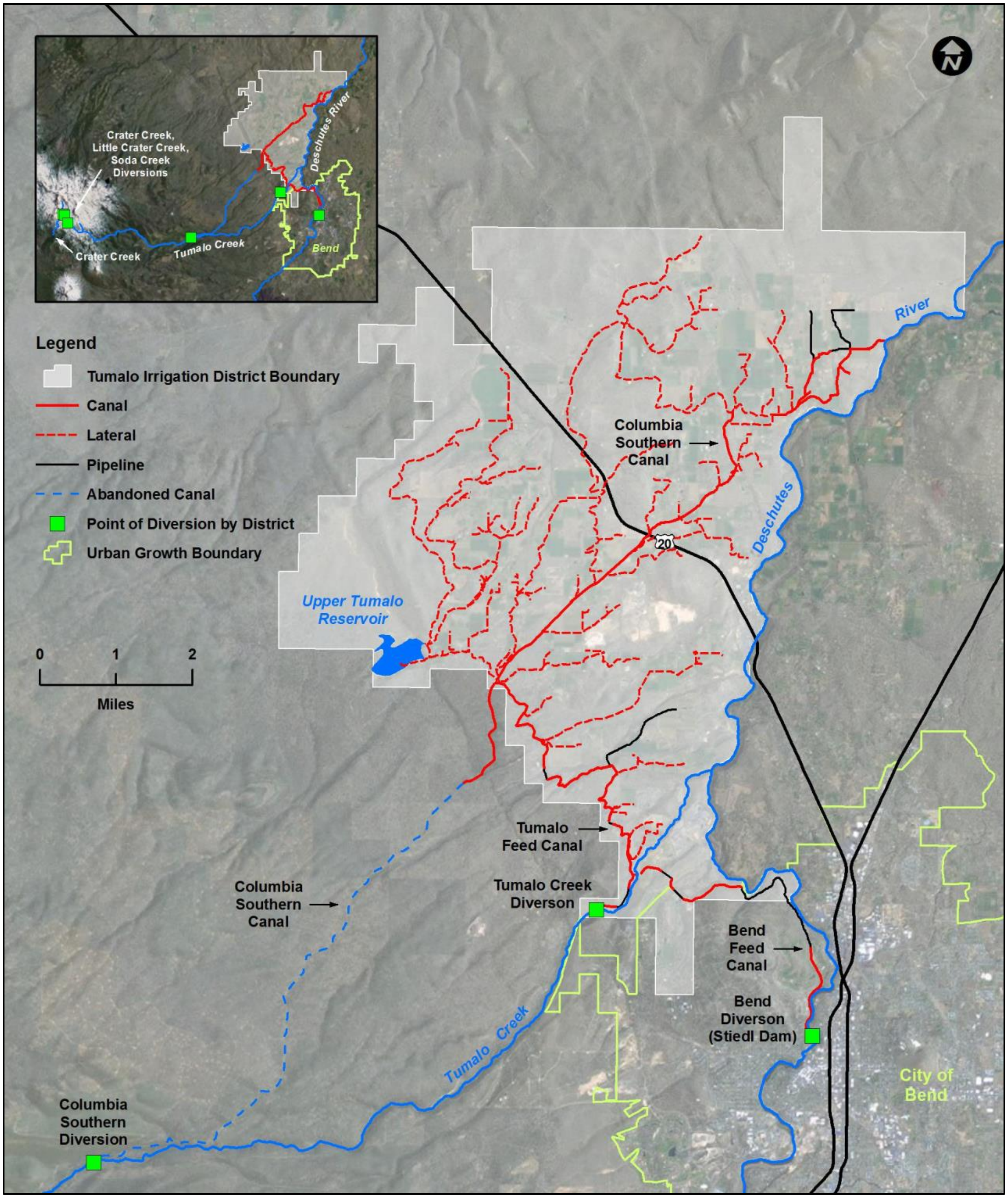

Figure 2-5. Map of Tumalo Irrigation District showing authorized points of diversion.

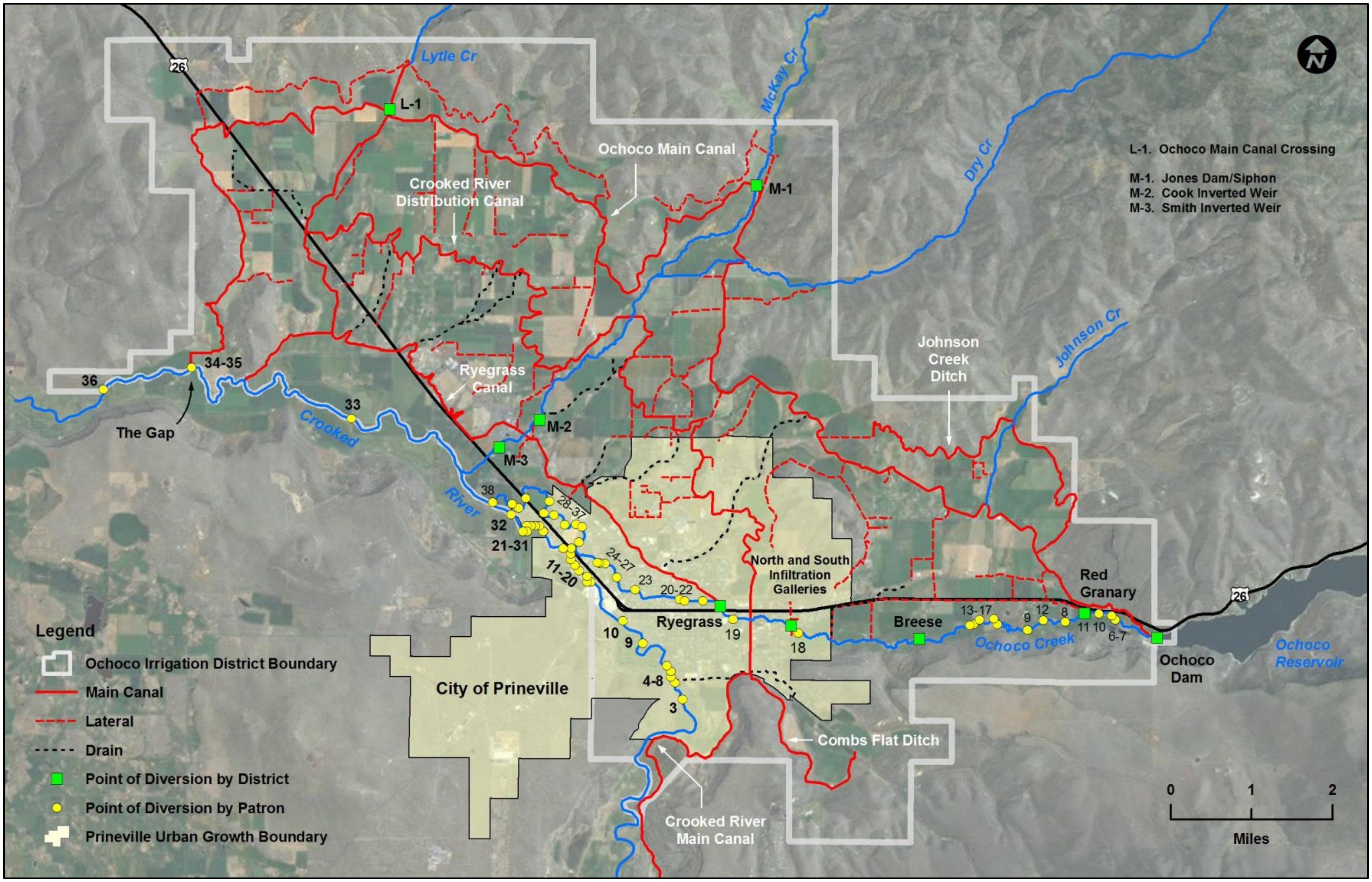

Figure 2-6. Map of Ochoco Irrigation District showing authorized points of diversion.

Table 2-1. Points of diversion covered by the DBHCP.

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
DESCHUTES RIVER								
Arnold Diversion	gravity	150.0	174.6	None	yes	no	The Arnold Diversion partially spans the Deschutes River, and does not preclude fish movement. The intake is screened.	No evaluations warranted at this time.
AID 2	pump	0.0098	174.0	None	no	no	The Arnold pumps do not interfere with fish movement. All intakes are unscreened. All are above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	No evaluations warranted at this time.
AID 3	pump	0.0043	172.3	None	no	no		
AID 4	pump	0.0092	172.3	None	no	no		
AID 5	pump	0.0061	172.1	None	no	no		
AID 6	pump	0.4473	171.3	None	no	no		
AID 7	pump	0.0049	165.8	None	no	no		
Central Oregon Headworks	gravity	800	170.9	None	yes	no	Water is diverted into the Central Oregon Headworks by a natural feature that does not interfere with fish passage. The intake is screened.	Screens were evaluated by ODFW (2000) and USFWS (2000) and considered acceptable.
COID 13	gravity	0.8710	167.8	None	yes	no	This pump does not interfere with fish passage. It is screened. It is above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	Screen was evaluated (ODFW and OWRD 2009) and found to meet state criteria.

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
COID 3	pump	0.0360	167.2	None	no	no	These pumps do not interfere with fish passage. All are unscreened. All are above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	No evaluations warranted at this time.
COID-4	pump	0.2550	167.0	None	no	no		
COID 5	pump	0.2020	166.7	None	no	no		
COID 6	pump	0.0800	166.7	None	no	no		
COID 7	pump	0.0190	166.0	None	no	no		
COID 8	pump	0.0710	165.9	None	no	no		
COID 10	pump	1.4260	165.0	None	Yes	no	This pump does not interfere with fish passage. It is screened. It is above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	Screen was evaluated (ODFW 2010) and found to meet state criteria.
Pilot Butte Canal Headworks	gravity	610	164.8	None	yes	yes	Pilot Butte Canal Headworks is located at North Canal Dam. The dam currently blocks upstream fish passage, but ODFW is evaluating it for passage. The intake is screened. North Canal Dam is above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	ODFW (2005) evaluated these screens and determined they meet state criteria for trout, kokanee and other resident fish.
COID 12	pump	0.0420	145.3	None	no	no	This pump does not interfere with fish passage. It is unscreened. It is above Big Falls; permanently outside the range of covered	No evaluation warranted at this time.

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
							steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	
North Unit Canal Headworks	gravity	1,100.0	164.8	None	yes	yes	North Canal Headworks is located at North Canal Dam. The dam currently blocks upstream fish passage, but ODFW is evaluating it for passage. The intake has screens constructed in 1946. North Canal Dam is above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	Evaluation by Reclamation (1999) indicated the screens do not meet current ODFW criteria for approach velocity, sweep velocity, or mesh size.
SID 0.5	pump	0.409	168.5	None	unknown	no	These pumps do not interfere with fish passage. Two pumps are screened, although they may not meet ODFW criteria for resident fish. All are above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	No evaluations warranted at this time.
SID 1	pump	< 1.0	166.2	None	unknown	no		
SID 2A	pump	< 1.0	165.9	None	yes	no		
SID 2B	pump	< 1.0	165.9	None	yes	no		
SID 2C	pump	< 1.0	165.9	None	unknown	no		
Swalley Headworks	gravity	87.0	164.8	None	yes	yes	Swalley Headworks is located at North Canal Dam. The dam currently blocks upstream fish passage, but ODFW is evaluating it for passage. The intake is screened. North Canal Dam is	ODFW (2005) evaluated these screens and determined they meet state criteria for

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
							above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	trout, kokanee and other resident fish.
SID 4	pump	< 1.0	164.0	None	unknown	no	These pumps do not interfere with fish passage. Several are screened, although they may not meet ODFW criteria for resident fish. All are above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	No evaluations warranted at this time.
SID 6A	pump	< 1.0	163.3	None	unknown	no		
SID 6B	pump	< 1.0	163.3	None	unknown	no		
SID 7	pump	< 1.0	163.1	None	yes	no		
SID 8	pump	< 1.0	163.1	None	yes	no		
SID 9	pump	< 1.0	159.3	None	yes	no		
SID 10	pump	< 1.0	156.7	None	yes	no		
SID 11	pump	< 1.0	156.5	None	yes	no		
SID 12	pump	< 1.0	154.9	None	unknown	no		
SID 13	pump	< 1.0	154.6	None	unknown	no		
SID 14A	pump	unknown	154.1	None	yes	no		
SID 14B	pump	< 1.0	152.4	None	yes	no		
SID 15	pump	< 1.0	152.0	None	unknown	no		
SID 16	pump	2.64	145.3	None	unknown	no		
Bend Diversion (Stiedl Dam)	gravity	140.0	165.9	None	yes	no	The Bend diversion has vertical, perforated stainless-steel plate fish screens with automatic wiper brushes, and a fish ladder that allows volitional upstream and downstream passage. Both the	Screens were installed in 2004 and approved by ODFW. The fish passage facility was also

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
							screens and ladder were constructed in coordination with ODFW. The diversion is above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	approved by ODFW.
TUMALO CREEK								
Tumalo Creek Diversion	gravity	190.0	2.8	None	yes	no	The Tumalo Creek Diversion has vertical, perforated stainless-steel plate fish screens with automatic wiper brushes, and a fish ladder that allows volitional upstream and downstream passage. Both the screens and ladder were constructed in coordination with ODFW. Tumalo Creek Diversion is above Big Falls; permanently outside the range of covered steelhead trout. Bull trout currently do not occur in this reach of the Deschutes River, and USFWS currently has no proposal to reintroduce bull trout.	Screens installed in 2006 and ladder updated in 2011 are both approved by ODFW.
CRATER CREEK, LITTLE CRATER CREEK AND SODA CREEK								
Crater Creek Diversion	gravity	40.0	[3/]	None	no	no	Creek is outside the range of covered species.	No evaluation warranted.
Little Crater Creek Diversion	gravity	34.0	[3/]	None	no	no	Creek is outside the range of covered species.	No evaluation warranted.
Soda Creek Diversion	gravity	1.0	[3/]	None	no	no	Creek is outside the range of covered species.	No evaluation warranted.

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
WHYCHUS CREEK								
TSID Whychus Creek Dam	gravity	160.0	24.2	steelhead, spring Chinook, bull trout[1]	yes	no	Whychus Creek Dam was recently reconstructed to eliminate obstruction of fish passage. The intake is screened.	Screens at Whychus Creek Dam meet NMFS criteria.
CROOKED RIVER								
NUID Crooked River Pumping Plant	pumps	200.0	27.6	steelhead, spring Chinook, bull trout[2]	yes	unknown	This pumps are screened and do not interfere with fish passage. Water is pooled downstream of the pumps by a notched rock berm to facilitate proper functioning of the screens and provide passage during low flows. Currently, steelhead trout have access to the affected reach of the Crooked River. Bull trout may have access during the term of the HCP.	Correspondence with ODFW (2012b) indicates screens meet NMFS criteria. Effects of the notched berm on fish passage are unknown.
Crooked River Diversion	gravity	190.0	56.5	steelhead, spring Chinook, bull trout[2]	yes	no	The Diversion has fish passage and the intake is screened. Currently, steelhead trout have access to the affected reach of the Crooked River. Bull trout may have access during the term of the HCP.	Correspondence with ODFW (2012b) indicates screens meet NMFS criteria.
OID Crooked River 3	pump	< 0.01	49.8	steelhead, spring Chinook, bull trout[2]	no	no	These pumps do not interfere with fish passage. All are unscreened. Currently, steelhead trout have access to the affected reach of the Crooked River. Bull trout may have access during the term of the HCP.	All pumps are currently unscreened. Screening is warranted under the HCP. Current evaluation should be limited to
OID Crooked River 4	pump	< 0.01	49.5	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 5	pump	< 0.01	49.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 6	pump	< 0.01	49.3	steelhead, spring Chinook, bull trout[2]	no	no		

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
OID Crooked River 7	pump	< 0.01	49.3	steelhead, spring Chinook, bull trout[2]	no	no		preliminary estimates of screening costs based on capacity and information available from OID. No field evaluations warranted at this time.
OID Crooked River 8	pump	< 0.01	49.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 9	pump	< 0.01	48.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 10	pump	< 0.01	48.1	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 11	pump	< 0.01	47.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 12	pump	< 0.01	47.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 13	pump	< 0.01	47.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 14	pump	< 0.01	47.2	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 15	pump	< 0.01	47.1	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 16	pump	< 0.01	47.1	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 17	pump	< 0.01	47.0	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 18	pump	< 0.01	46.9	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 19	pump	< 0.01	46.9	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 20	pump	< 0.01	46.8	steelhead, spring Chinook, bull trout[2]	no	no		

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
OID Crooked River 21	pump	< 0.01	46.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 22	pump	< 0.01	46.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 23	pump	< 0.01	46.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 24	pump	< 0.01	46.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 25	pump	< 0.01	46.3	steelhead, spring Chinook, bull trout[1]	no	no		
OID Crooked River 26	pump	< 0.01	46.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 27	pump	< 0.01	46.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 28	pump	< 0.01	46.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 29	pump	< 0.01	46.2	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 30	pump	< 0.01	46.2	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 31	pump	< 0.01	46.1	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 32	pump	0.40	45.9	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 33	pump	2.60	42.9	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 34	pump	2.50	39.6	steelhead, spring Chinook, bull trout[2]	no	no		

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
OID Crooked River 35	pump	2.50	39.6	steelhead, spring Chinook, bull trout[2]	no	no		
OID Crooked River 36	pump	0.70	38.4	steelhead, spring Chinook, bull trout[2]	no	no		
City of Prineville	pump	1.00	45.9	steelhead, spring Chinook, bull trout[2]	Yes	no	This pump does not interfere with fish passage. It is screened. Currently, steelhead trout and Chinook salmon juveniles have access to the affected reach of the Crooked River. Bull trout may have foraging access when flow and temperature conditions allow during the term of the HCP.	Screen does not meet NMFS criteria.
OCHOCO CREEK								
Ochoco Dam	gravity	140.0	11.2	steelhead, spring Chinook, bull trout[2]	no	yes	The dam currently has no screens or passage. No covered species are currently present above the dam. Covered fish species could reach the base of the dam during the DBHCP	Since the intake is unscreened, evaluation of screens is not necessary.
Red Granary Diversion	gravity	30.0	10.2	steelhead, spring Chinook, bull trout[2]	yes	no	This inflatable dam has passage and screens. The screens have 3/32-inch openings, and can be operated to maintain approach velocity at or below 0.4 feet/second.	Correspondence with ODFW (2012b) indicates screens meet state criteria.
Breese Diversion	gravity and pump	10.0	7.5	steelhead, spring Chinook, bull trout[2]	yes	no	This inverted weir has fish screens and includes passage.	Evaluated for this study (see Section 2.7.4).
North/South Infiltration Galleries	pumps	2.0/1.0	5.7	steelhead, spring Chinook, bull trout[2]	no	no	There is no risk of fish entrainment with subsurface intakes, and they do not hinder fish passage.	No evaluation warranted.

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
Ryegrass Diversion	gravity	10.0	4.7	steelhead, spring Chinook, bull trout[2]	yes	no	This inverted weir has fish screens and passage.	Fish screens and passage were evaluated by Rose et al. (2005). Correspondence with ODFW (2012b) indicates screens meet state criteria.
OID Ochoco 6	pump	0.45	10.6	steelhead, spring Chinook, bull trout[2]	no	no	These pumps do not interfere with fish passage. Most are unscreened. Currently, steelhead trout and spring Chinook have access to the affected reach of Ochoco Creek. Bull trout may have access during the term of the DBHCP.	Most pumps are currently unscreened. Screening is warranted under the DBHCP. Current evaluation should be limited to preliminary estimate of screening costs based on capacity and information available from OID. No field evaluations warranted at this time.
OID Ochoco 7	pump	0.60	10.6	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 8	pump	0.30	9.9	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 9	pump	0.50	9.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 10	pump	0.25	10.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 11	pump	0.60	10.2	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 12	pump	0.50	9.6	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 13	pump	0.15	8.7	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 14	pump	0.30	8.6	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 15	pump	0.25	8.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 16	pump	0.20	8.4	steelhead, spring Chinook, bull trout[2]	no	no		

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
OID Ochoco 17	pump	0.75	8.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 18	pump	0.75	5.8	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 19	pump	unknown	4.9	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 20	pump	0.05	4.1	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 21	pump	0.30	4.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 22	pump	0.15	4.2	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 23	pump	0.20	3.5	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 24	pump	0.20	3.2	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 25	pump	0.15	2.9	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 26	pump	0.10	2.8	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 27	pump	0.10	2.8	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 28	pump	0.25	2.3	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 29	pump	0.50	2.0	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 30	pump	0.20	2.1	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 31	pump	0.05	1.6	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 32	pump	0.20	1.8	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 33	pump	0.20	1.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 34	pump	0.30	1.3	steelhead, spring Chinook, bull trout[2]	no	no		

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
OID Ochoco 35	pump	0.50	0.7	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 36	pump	0.30	0.5	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 37	pump	0.35	0.4	steelhead, spring Chinook, bull trout[2]	no	no		
OID Ochoco 38	pump	0.75	0.0	steelhead, spring Chinook, bull trout[2]	no	no		
JOHNSON CREEK								
Multiple locations	gravity and pump	unknown	-	None	no	no	Johnson Creek is a non-fish stream used for irrigation conveyance. Screens and passage are not warranted.	No evaluations warranted.
DRY CREEK								
Multiple (4) locations	gravity and pump	unknown	-	None	no	no	Dry Creek is a non-fish stream used for irrigation conveyance. Screens and passage are not warranted.	No evaluations warranted.
MCKAY CREEK								
Jones Dam/Siphon	gravity	40.0	5.8	steelhead, spring Chinook, bull trout[2]	yes	no	This check-board structure has fish screens built in 2001 and passage constructed in 2011.	Screens were built by ODFW in 2001 to comply with NMFS criteria at a design flow of 40 cfs.
Reynolds Siphon	gravity	n/a	3.2	steelhead, spring Chinook, bull trout[2]	n/a	n/a	This diversion is currently inactive. Screens and passage are not warranted.	No evaluation warranted at this time.
Cook Inverted Weir	gravity	5.0	1.3	steelhead, spring Chinook, bull trout[2]	yes	no	This inverted weir has fish screens and passage.	Fish screens and passage were

Name	Diversion Type	Capacity (cfs)	Location (RM)	Covered Fish Species Present or Potentially Present	Screens Present	Blockage to Fish Passage	Comments	Evaluation
								evaluated by Rose et al. (2005).
Pine Products Siphon	gravity	n/a	1.0	steelhead, spring Chinook, bull trout[2]	n/a	n/a	This diversion is currently inactive. Screens and passage are not warranted.	No evaluation warranted at this time.
Smith Inverted Weir	gravity	4.0	0.6	steelhead, spring Chinook, bull trout[2]	yes	no	This inverted weir has fish screens and passage.	Fish screens and passage were evaluated by Rose et al. (2005).
LYTLE CREEK								
Multiple (11) locations	gravity	unknown	-	steelhead,	no	yes	OID uses Lytle Creek for irrigation conveyance, with 11 diversions from the creek above RM 0.5. All diversions are unscreened and may seasonally block the creek. Covered species currently do not utilize the creek above RM 0.5. Future use of the creek by covered species is uncertain.	No evaluations warranted at this time.

1 Bull trout are currently limited to the lower 5.7 miles of Whychus Creek. Future bull trout use of the creek above RM 2.4 is uncertain.

2 Bull trout currently do not exist above Opal Springs Dam at RM 7.0 on the Crooked River. Volitional fish passage will be provided at Opal Springs Dam no later than 2016. It is not known how bull trout will use the Crooked River above RM 7.0 once passage is provided. Critical habitat for bull trout spawning and rearing is only designated upstream to HWY 97 at RM 18, downstream of considerable groundwater inflow in this basin. It is possible bull trout could use habitats upstream of HWY 97 for opportunistic foraging when river flows and water temperatures allow.

3 Near headwaters

2.2. Deschutes River

2.2.1. Potential Presence of Covered Fish Species

All covered points of diversion on the Deschutes River are above Big Falls, and therefore, outside the area potentially occupied by reintroduced steelhead, and salmon. Bull trout occurred historically in the Upper Deschutes Basin, but they are currently considered extirpated above Big Falls (Buchanan et al. 1997). The covered points of diversion on the Deschutes River have not been evaluated for entrainment or passage of anadromous fish in this document, but ODFW evaluated several of these diversions for resident fish passage. The ODFW evaluations are noted where appropriate in the following sections.

2.2.2. Arnold Diversion

Fish Passage: The Arnold Diversion is owned and operated by Arnold Irrigation District (AID). The diversion is located at RM 174.6, about 5 miles south of Bend. The facility is upstream of river reaches accessible to covered fish species.

The diversion consists of a 15-inch high concrete structure that partially spans the river from an island to the right (east) bank and directs flow into the headworks. Under normal operating conditions, fish passage along the west side of the river is unobstructed. Under extreme low flow conditions, AID can erect temporary, 2-foot high splash boards between the island and the left (west) bank of the river to direct additional flow into the headworks. The flash boards do not span the entire channel, however, and upstream fish passage remains unimpeded. The temporary splash boards are removed when not in use. No other provisions for fish passage are provided at the Arnold Diversion.

Screens: The Arnold intake has a capacity of 150 cubic feet per second (cfs). The diversion is equipped with fish screens that return fish to the river approximately 234 feet downstream of the diversion. These screens are vertical, perforated stainless-steel, flat-plate screens with automated wiper brushes. Each screen panel measures 4.0 feet wide by 3.5 feet high. The panels have 3/32-inch holes on 5/32-inch centers. Total open area on each panel is 33 percent. The screens were installed in 2000. The new screens at the Arnold Diversion were partially funded, inspected, and approved by ODFW shortly after installation in 2001. To date, ODFW has not provided written verification of the inspection and approval process.

2.2.3. Arnold Irrigation District Patron Pumps

Six AID patrons pump water directly from the Deschutes River between RM 174.0 and RM 165.8. These pumps draw between 0.0043 and 0.4473 cfs each and total <0.5 cfs combined. None of the pumps obstruct fish passage, and none are screened to exclude fish. All six pumps are above Big Falls, and therefore outside the current and anticipated ranges of covered fish species.

2.2.4. Central Oregon Headworks

Fish Passage: The Central Oregon Headworks diverts water into the Central Oregon Irrigation Districts (COID) Central Oregon Canal at RM 170.9 on the Deschutes River. There is no diversion structure at this location. Natural stream morphology is used to capture and direct flows without a dam or other obstruction of the river. No provisions for fish passage are necessary at the headworks.

Screens: The Central Oregon Headworks has a capacity of 1,385 cfs. It is screened to exclude fish. These screens are vertical plate with 1/8-inch holes and an automated cleaning mechanism. They were inspected in 1999 by USFWS and ODFW, and subsequently evaluated for effectiveness by COID. After reviewing COID's evaluation report, USFWS (2000) and ODFW (2000) determined the screens were functioning properly and had acceptable rates of survival (98.4% for redband trout fry and 94.4% for kokanee fry). Both agencies recommended inspection and maintenance of the screens at the beginning and end of each irrigation season to ensure they continue to function properly.

2.2.5. Central Oregon Irrigation District Patron Pumps

COID patrons remove water directly from the Deschutes River at nine points of diversion between RM 167.8 and RM 145.3 totaling 3.0 cfs. All but one of these diversions occur within the city limits of Bend and upstream of the North Canal Dam. The last one is at Cline Falls State Park, just upstream of Highway 126. None of the diversions impede fish movement. The largest patron diversion (COID 10), a screened pump withdrawing up to 1.426 cfs, is designed to meet ODFW criteria for resident fish (ODFW 2010). The second largest (COID 13) is a gravity diversion withdrawing up to 0.871 cfs with flat panel screens that also meet state criteria for resident fish (ODFW and OWRD 2009). The remaining seven pumps draw between 0.0219 and 0.255 cfs each and are unscreened. All nine points of diversion are above Big Falls, and therefore outside the current and anticipated ranges of covered fish species.

2.2.6. Pilot Butte Canal Headworks and Swalley Headworks

Fish Passage: The Pilot Butte Canal Headworks is owned and operated by COID. The Swalley Headworks is owned and operated by Swalley Irrigation District (SID). The two districts share a common intake structure on the North Canal Diversion Dam at RM 164.8 in Bend. The dam is a 40-foot high concrete-arch structure that blocks upstream fish passage. COID, SID, and NUID recently entered into an agreement with ODFW to jointly fund the design and construction of a fish ladder at the dam. Construction is anticipated to be completed by 2016, provided ODFW can obtain the necessary funding.

Screens: The intakes to the Pilot Butte Canal Headworks and the Swalley Headworks are screened to preclude fish entrainment. These structures are vertical, flat-plate, perforated stainless-steel screens with automated wiper brushes. Both sets of screens share a common return, which releases fish approximately 300 feet below North Canal Diversion Dam. ODFW (2005) evaluated the screens and verified they meet state criteria for resident fish.

2.2.7. North Unit Canal Headworks

Fish Passage: The North Unit Canal Headworks is a federal (Reclamation) facility operated by NUID. It is also located behind North Canal Diversion Dam at RM 164.8. As noted above, NUID is a party to the agreement to fund design and construction of upstream fish passage at the dam. In the meantime, the dam blocks all upstream fish passage.

Screens: The intake to the North Unit Canal Headworks has fish screens constructed in 1946. They consist of two rotary drums, each measuring 14.5 feet in diameter and 24 feet long. They are covered with 0.25-inch woven wire mesh, and sealed at the sides and bottoms with rubber strips. Trash racks in front of the screens have bars on 4-inch centers. Reclamation (1999) evaluated the screens, and found they did not meet ODFW criteria for: a) approach velocity, b) sweep velocity, and c) mesh size (openings). Reclamation also noted the seals along the sides and bottoms are not tight, and the facility lacks downstream bypass. No substantial changes have been made to the screens since the 1999 evaluation, although downstream fish bypass at North Canal Diversion Dam is now provided at the screens for the Swalley and Pilot Butte canal intakes.

2.2.8. Swalley Irrigation District Patron Pumps

A portion of SID's water right is withdrawn directly from the Deschutes River at 15 points of diversion (19 pumps) between RM 168.5 and RM 145.3. The pumps draw between 0.01 and 2.64 cfs each. None of the pumps impede fish movement. Several of the pump intakes are screened, however, most are not screened. None of the existing screens have been evaluated by ODFW and few are likely to meet state criteria for resident fish. All 15 points of diversion are above Big Falls, and therefore outside the current and anticipated ranges of covered fish species.

2.2.9. Bend Diversion (Stiedl Dam)

Fish Passage: Tumalo Irrigation District (TID) owns and operates the Bend Diversion (also known as Stiedl Dam) at RM 165.9. Originally built in 1922, the 6-foot high overflow structure was extensively upgraded in 1975. A fish ladder was included in the design to allow volitional upstream and downstream passage at the diversion.

Screens: The intake at the Bend Diversion has a capacity of 140 cfs. It has vertical, flat-plate, perforated stainless-steel screens with automatic wiper brushes that were installed in 2004. These screens meet ODFW criteria for resident fish.

2.3. Tumalo Creek

2.3.1. Potential Presence of Covered Species

Tumalo Creek is a tributary to the Deschutes River at RM 160, above Big Falls. The entire creek is outside the potential reintroduction areas for steelhead trout and salmon. Historical presence of bull trout in Tumalo Creek is uncertain, but the species is currently absent from the creek.

2.3.2. Tumalo Creek Diversion

Fish Passage: The Tumalo Creek Diversion withdraws water at RM 2.8 on Tumalo Creek. The diversion is a 4-foot overflow structure with a fish ladder that was most recently upgraded in 2011. The ladder meets ODFW criteria for upstream and downstream passage.

Screens: The intake at the Tumalo Creek Diversion has a capacity of 190 cfs. It has vertical, flat-plate, perforated stainless-steel screens with automatic wiper brushes. The screens were installed in 2006 and currently meet ODFW criteria for resident fish (ODFW 2012b).

2.4. Crater Creek, Little Crater Creek, and Soda Creek

2.4.1. Potential Presence of Covered Species

Crater, Little Crater, and Soda creeks are seasonal streams that drain into Sparks Lake, a terminal alpine lake west of the Tumalo Creek basin. The creeks flow primarily in response to spring snowmelt. They are outside the potential reintroduction areas for steelhead trout and salmon, and have no history of bull trout use.

2.4.2. Crater Creek, Little Crater Creek, and Soda Creek Diversions

Small instream diversion structures direct water from Crater, Little Crater, and Soda creeks into an unlined ditch along the south side of Broken Top Mountain. The ditch conveys the water about 2 miles into the Middle Fork Tumalo Creek. The canal has a capacity of 75 cfs, and functions mainly to capture snowmelt during the spring. The diversions have no provisions for fish passage or screening.

2.5. Whychus Creek

2.5.1. Potential Presence of Covered Species

Whychus Creek is a tributary to the Deschutes River at RM 123.1, entering the mainstem between Big Falls and Lake Billy Chinook. Juvenile steelhead trout have been reintroduced into Whychus Creek, and returning adults are expected to have access upstream to a natural falls at RM 37.1. In a similar manner, reintroduced spring Chinook salmon can be expected to spawn and rear up to RM 37.1. Bull trout are known to forage in the lower 0.8 mile of the Whychus Creek where inflow from Alder Springs maintains suitable water temperatures. They may migrate another 4.1 miles upstream to RM 5.7 (USFWS 2010), but under current conditions have not reached the Whychus Creek Diversion Dam at RM 24.2.

2.5.2. Whychus Creek Diversion

Fish Passage: TSID owns and operates the Whychus Creek diversion at RM 24.2. The diversion was rebuilt in conjunction with a stream restoration effort in 2010. It is a low concrete structure that fish can swim over in the upstream and downstream directions. A V-notch near the left abutment (opposite the intake) ensures volitional passage at low flows.

Screens: The intake at Whychus Creek Dam has a capacity of 160 cfs. The Farmers Conservation Alliance-type fish screen constructed in 2011 is approximately 140 feet in length and horizontally aligned so the water flows parallel to, and over, the top of the screen. Fish entering the diversion pass over the screens and are returned to the creek through a separate bypass pipe prior to entering the irrigation system approximately 300 feet downstream of the intake. Fish are unable to evade the return pipe because the water velocity exceeds the fishes' burst swimming speed.

The holes in the fish screen are 3/32 inch, designed to exclude small fish fry. Water flow is monitored and controlled to ensure safe fish passage. The screens are designed to meet ODFW and NMFS criteria for resident and anadromous fish.

2.6. Crooked River

2.6.1. Potential Presence of Covered Species

Juvenile steelhead trout and spring Chinook salmon have been reintroduced into the Crooked River, where returning adults will have access as far as Bowman Dam at RM 70.5. Bull trout currently have access to the Crooked River up to Opal Springs Dam at about RM 7.2. Installation of a fish ladder at the dam will provide volitional access for migrating salmon and trout species no later than 2016. The presence of bull trout in the mainstem Crooked River above Opal Springs Dam after 2016 will likely be a function of stream flow and water temperature conditions. Adults may forage temporarily upstream of this point when conditions are favorable.

2.6.2. Crooked River Diversion

Fish Passage: The Crooked River Diversion is a federally-owned facility operated by OID at about RM 56.5. Flows are directed to the headworks by a 4-foot high sheet pile diversion weir. The weir has an 84-foot-wide high flow V-notch and an 18-foot low flow V-notch to concentrate flows.

During the irrigation season, water is allowed to pass over the weir for downstream withdrawal by OID and others, and to maintain instream flows in the Crooked River. Reclamation and OID attempt to pass sufficient flow to satisfy downstream withdrawals and still maintain at least 10 to 30 cfs in the reach between the Meadow Lakes Golf Course (RM 49.2) and Ochoco Creek (RM 45.6). The amount of water passed over the weir to accomplish this objective varies, depending on irrigation demands, and typically ranges between 40 and 60 cfs. Reclamation (2001) describes the minimum design flow as 50 cfs. These flows enable OID to meet fish passage criteria specified by USFWS and ODFW for a minimum flow depth of 1 foot over the weir and a minimum depth of 3 feet in the step pools downstream of the weir (Reclamation 2001).

Screens: The headworks structure at the Crooked River Diversion has a maximum capacity of 190 cfs. The diversion was fitted with new fish screens in 2001. The screens are vertical-plates with a traveling brush cleaning system. The screens consist of ten 8-foot long and 8.5-foot high stainless steel panels, with 3/32-inch holes on staggered 5/32-inch centers that provide 33 percent open area. The screens have louvers to regulate through-flow and maintain approach velocity at 0.4 feet per second (fps) or less at flows up to 163 cfs (the 90 percent exceedance flow for the canal). Fish are directed into a 30-inch bypass pipe and returned to the Crooked River 375 feet downstream of the diversion. Recent correspondence with ODFW (2012b) indicates the screens meet state criteria for resident fish.

2.6.3. North Unit Irrigation District Crooked River Pump

Fish Passage: NUID owns and operates a pumping plant on the south bank of the Crooked River at RM 27.6. The plant is designed to accommodate NUID's full Crooked River water right of 200 cfs, but it generally pumps 144 cfs or less to avoid pump damage. As required by the State of Oregon, NUID allows at least 10 cfs to pass the pumping plant and remain in the Crooked River. A low berm of unconsolidated streambed material is maintained in the river just downstream of the pumps to pool water at the intakes. The berm has a notch to concentrate low flows and facilitate fish passage. The effects of the notched berm on fish movement have not been assessed and currently are unknown.

Screens: In 2008, the pumps were fitted with Hydrolox™ Series 1800 polymer vertical traveling screens with Intralox Series-1800 mesh. Each of nine screen panels measures 4.5 feet wide by approximately 15 feet high. Reclamation (2004) assessed the *Intralox* screen surface mesh on a traveling screen under laboratory conditions. They concluded the screen material generated uniform approach and sweep velocity conditions and that rainbow trout avoided the screen surface. Similarly, correspondence from NOAA in 2003 indicated the Intralox Series-1800 fish screen mesh met all aspects of the NMFS criteria for slotted screen face materials for the protection of fry-size and larger salmonid fishes (Nordlund 2003; Wantuck 2003). Recent correspondence with ODFW (2012) indicates the screens meet biological criteria for resident fish.

2.6.4. Ochoco Irrigation District Crooked River Pumps

OID patrons remove water directly from the Crooked River at 34 pumps between RM 38.4 and RM 49.8). Twenty-nine of the pumps draw less than 0.01 cfs. The remaining five pumps draw between 0.4 and 2.6 cfs. None of the pumps impede fish passage in the river. None are screened to prevent fish entrainment.

2.6.5. City of Prineville Irrigation Pumps

The City of Prineville pumps water from the Crooked River to irrigate the Meadow Lakes Golf Course. Primary irrigation for the golf course is provided by the City's sewage treatment effluent, but water from the Crooked River is used when the volume of effluent is insufficient. The pump is located at RM 45.9, approximately 0.3 mile upstream from the confluence with Ochoco Creek, and has a capacity of 1.0 cfs. The intake consists of a 30-horsepower sump pump including a 14-inch pipe within a 4-foot concrete culvert stilling basin. Since the intake is a fixed-rate pump, the City diverts more water than required for irrigation and releases the balance in a bypass channel back to the Crooked River.

The intake is located at the terminal end of a dead-end excavated channel (Figure 2-7) with a temporary vertical flat-plate fish screen blocking the inlet canal to the pump. The passive screen is a 4-foot by 8-foot panel with 3/32-inch screen mesh that guards the channel leading from the Crooked River to the pump (Figure 2-8). The removable screen is designed to mechanically drop into grooved side slots for a rigid, perpendicular orientation to the inlet channel. However, the screen is only a partial deterrent to fish exclusion, since the rectangular structure does not completely block the sides or the bottom of the channel. The screen has no sweeping velocity, no fish bypass, and no cleaning capability (other than removing it for cleaning). The screen does not comply with NFMS criteria for fish passage facilities.

Figure 2-7. City of Prineville inlet channel from the Crooked River at RM 45.9.

Figure 2-8. City of Prineville vertical plate fish screen.

2.7. Ochoco Creek

2.7.1. Potential Presence of Covered Species

Steelhead trout and spring Chinook salmon currently have access to Ochoco Creek from the mouth to Ochoco Dam (RM 11.2) due to ongoing reintroduction efforts. Bull trout and sockeye salmon are not known to occur in Ochoco Creek. The presence of bull trout in the river system upstream of Opal Springs Dam after passage is provided will likely be a function of water temperature, since the river upstream of Hwy 97 is generally too warm to support bull trout spawning or rearing. Adults may forage temporarily upstream of this point when conditions are favorable. No covered fish species are present above Ochoco dam.

2.7.2. Ochoco Dam

Fish Passage: Ochoco Dam is an earthfill structure that impounds 1,060-acre Ochoco Reservoir at RM 11.2 on Ochoco Creek. With a crest elevation of 125 feet, the dam is an impassable barrier to upstream fish passage. The dam has no provisions for upstream or downstream fish passage. The State of Oregon, through the Deschutes River Conservancy, annually leases between 7 to 10 cfs of water to be released for instream flow purposes in Ochoco Creek during the irrigation season. Among other benefits, this flow assists in upstream and downstream passage throughout the length of Ochoco Creek for various life history stages of covered fish species.

Screens: Water is released from Ochoco Reservoir through an unscreened outlet pipe in the dam. The outlet pipe has a controlled capacity of 430 cfs. The upstream end (inlet) of the pipe is approximately 56 feet below the full pool level of the reservoir. The downstream end of the pipe enters the Ochoco Main Canal at the headworks. The headworks are screened to exclude fish from the canal and return them to the creek below the dam, but the screens do not meet NMFS criteria.

2.7.3. Red Granary Diversion

Fish Passage: Red Granary Diversion is an inflatable Obermeier dam supported by a concrete apron and walls at about RM 10.2 on Ochoco Creek. The dam can be raised to a height of 4 feet to divert up to 30 cfs, or lowered to allow unrestricted flow of the creek. It is fitted with a fish ladder to allow upstream and downstream movement when the dam is raised.

Screens: The fish screens at Red Granary diversion are integral to the fish ladder constructed by ODFW in 2001. The screen surface consists of vertical plates with 3/32-inch openings. They are approximately 4 feet high and 20 feet long, and can be operated to maintain approach velocity at or below 0.4 fps. The surface material and approach velocity are designed to comply with the NMFS criteria for fry-sized fish with active cleaning systems. The screens are cleaned by electric-powered gang brushes. Fish are returned to the creek immediately below the dam. Recent correspondence with ODFW (2012b) indicates the screens meet biological criteria for resident fish.

2.7.4. Breese Diversion

Fish Passage: Breese Diversion, constructed by OID in 1998, is an inverted weir at approximately RM 7.5 on Ochoco Creek. The diversion consists of a perforated 36-inch diameter steel pipe laid horizontal across the creek and bedded in concrete (Figure 2-9). The pipe serves as both a weir and an intake, as water is drawn by gravity through the perforated top. Water in the pipe continues by gravity flow to both streambanks, where it is pumped into OID canals. Each of the two pumps has a capacity of 5 cfs. The average operational withdrawal rate is typically half the rated capacity. The weir has a 2.5-foot deep V-notch to concentrate low flows and facilitate upstream and downstream fish movement. Since the V-notch is lower than the perforated screens, it also functions as an automatic diversion cutoff during low stream flows to ensure the weir cannot dry the creek. Thus, water is available for both upstream and downstream fish passage in Ochoco creek near the Breese Diversion.

Screens: The horizontal surface of the inverted weir at the Breese Diversion serves as a fish screen (Figure 2-10.). The perforated screen material includes panels with both 3/16–inch and 3/32-inch holes with the surface of the screens curved slightly in the downstream direction. Neither ODFW nor Reclamation has information on file for the Breese Diversion screens with respect to compliance with fish passage criteria. As a result, hydraulic measurements were collected during a DBHCP site visit on July 11, 2012 and the results were compared to NFMS experimental criteria for horizontal flat plate screens and to criteria for existing screens (Appendix A).

As described in Appendix A, the Breese Diversion was constructed and authorized by the state in accordance with available biological criteria existing in the late 1990s. Acceptance of ongoing operations falls under the existing screen criteria (§11.4 of the 2011 NMFS criteria). Other than one bent screen that requires repair, and the location of the intake near potential spawning and incubation habitats, the screens comply with the categorical approvals NMFS established for existing screens.

A comparison was also performed to assess how the current screen conditions would perform against the criteria for construction of new horizontal flat-plate screens. NMFS views the horizontal screens as experimental technology because they operate fundamentally different from conventional vertically-oriented screens. The Breese screens complied with the criteria and guidelines for: 1) *Site Limitations* (V-notch; fish passage; channel approach); 2) *Bypass Flow Amount* (more than 50% of diverted water); 3) *Diversion Shut-off* (V-notch); 4) *Approach Velocity* (maximum instantaneous design capacity < 0.25 fps); and 5*) Screen Materials* (smooth, corrosion resistant, durable surfaces, % open areas > 27%. The Breese intake screens would not likely comply with criteria and guidelines for: 1) *Screen Materials* (circular openings < 3/32 inch); 2) *Sweeping Velocity* (> 2.5 fps, and steady velocities across the screen face); 3*) Self-cleaning Screens* (sweeping to approach velocity ratio of > 20:1); and 4) *Monitoring Requirements*. It is unknown if the operation of the Breese Diversion would comply with NFMS criteria for *Sediment Removal* requirements.

Figure 2-9. Breese diversion structure in Ochoco Creek.

Figure 2-10. Breese horizontal perforated screen surface.

2.7.5. North and South Infiltration Galleries

These two infiltration galleries are located along the north and south sides of Ochoco Creek at about RM 5.7. The intakes were designed by the Natural Resource Conservation Service (NRCS) in 1998 using NRCS standards for water control structures (587) pumping plants (533) and pipes (430). The infiltration galleries were constructed in 2000 to replace instream diversion structures at the Slaughterhouse and Schnoor dams and the associated open, earth-lined ditches. The infiltration galleries consist of: 1) 12-inch by 20-foot perforated pipes laid beneath 6.5 to 9 feet of gravel and native materials and 2) associated sump pumps to bring the water to grade. The North Gallery diverts up to 2 cfs and the South Gallery diverts up to 1 cfs from the static water table in the streambank sediments adjacent to the creek. Since the infiltration galleries are located off-channel, neither gallery influences upstream or downstream fish passage and a hydraulic assessment to evaluate federal and state biological criteria is unnecessary.

2.7.6. Ryegrass Diversion

Fish Passage: Ryegrass Diversion is an inverted weir that diverts up to 10 cfs from Ochoco Creek at RM 4.7. A 36-inch diameter steel pipe is laid horizontal across the creek to serve as both a weir and an intake. Water passing over the weir is drawn by gravity through the top. At least 5 to 10 cfs of water typically is allowed to pass Ryegrass Diversion for withdrawal downstream or contribution to Ochoco Creek and Crooked River flows. The weir has a three-tiered V-notch to concentrate low flows and allow upstream and downstream fish movement. A step-pool on the downstream side of the weir facilitates upstream fish movement.

Screens: The horizontal surface of the Ryegrass inverted weir functions as a fish screen. The structure has seven 2-foot x 4-foot panels, with 0.07-inch (0.175 cm) profile bar screen material positioned perpendicular to flow. The screen panels have 4 percent gradients with a head differential of approximately 1.25 feet across the screen.

The USGS evaluated the weir and found the screen had approach velocities of 0.1 to 0.2 fps, and sweeping velocities of 2.3 to 3.2 fps, within the design diversion range of the weir and the range of streamflows observed during the 2004 and 2005 irrigation seasons (Rose et al. 2005). The mean sweeping velocities were found to be inversely related to the screen:weir ratio (linear length of the screens to linear length of the instream component of the weir). The high screen:weir ratio of 57 percent for the Ryegrass Diversion had relative low mean sweeping velocities.

Based on video surveillance of fish contacts with the screen surface, the USGS calculated the effects of hydraulic and biological variables on the level of screen contact rates for the horizontal plate, inverted weir design as follows:

Eqn. 1 **SC = 1.354 - 0.131(Z)**

Where: SC = Screen contact rate (number of observed contacts/total number of observed fish)

Z = Water depth over the screen (cm)

As a result of the research, Rose et al. (2005) recommended 2.8 to 4.0 inches of water over the screen surfaces to minimize fish abrasion. At Ryegrass, measured water depths over the screens averaged between 2 and 6 inches, which would provide a screen contact rate between 0 and 70 percent. Water depths were often shallower than average rates, leaving little water for fish passage. For example, the downstream third of the two screens nearest the Ryegrass diversion outflow were dewatered, potentially exposing fish to the screens. The dewatering was apparently caused by a combination of factors, including low stream discharge, high diversion rates, and excessive growth of aquatic vegetation near the screen that restricted stream flow near the dewatered area (Rose et al. 2005).

Rose et al. (2005) found the 24-hour survival rate for redband trout passing over the Ryegrass weir was over 99 percent. Up to 14 percent of fry and up to 79 percent of older fish passing over the weir received non-lethal injuries due to screen contact, but there were no statistically significant differences in the rates of injury between control fish (those passing over the weir when the screens were covered) and treatment fish (those with the potential to physically encounter the screens). Rose et al. (2005) concluded the inverted weir screens were safe and effective for salmonid fishes within the design range of diversions and the observed ranges of stream flow at the site.

According to Rose et al. (2005), the inverted weir screens accumulated debris at about 5 percent of the screen area per day. The authors noted that manual cleaning at intervals of 1 to 6 days was necessary to keep the screens free of debris. The OID ditch riders clean the screens daily during the irrigation season. NFMS found the self-cleaning ability of a horizontal screen is enhanced when the ratio of sweeping velocity and approach velocity exceeds 20:1 (NFMS 2011). The sweeping to approach velocity ratio at Ryegrass ranged between 17:1 and 23:1 offering a good level of self-cleaning of floating debris. Attached algae and periphyton continue to require daily physical cleaning.

Recent correspondence with ODFW (2012b) indicates the screens meet biological criteria for resident fish.

2.7.7. Ochoco Irrigation District Ochoco Creek Pumps

OID patrons remove water directly from Ochoco Creek at 33 pumps between RM 0.1 and RM 10.6. None of the pumps impede upstream or downstream fish passage in the river, and none are screened to prevent fish entrainment. Combined the pumps have a maximum diversion capacity of 10.5 cfs.

2.8. Johnson Creek

Johnson Creek is a seasonal non-fish stream used for conveyance of irrigation water. The creek terminates at the Ochoco Main Canal and is not accessible to covered fish species. OID diverts water from the creek and spills into the creek, depending on operational needs, at the Johnson Creek Canal crossing. Water is diverted out of the creek by multiple downstream patrons. Water remaining in the creek flows into the Ochoco Main Canal. Since Johnson Creek does not support fish, none of the OID or patron structures on the creek have fish passage facilities or screens. Johnson Creek is not evaluated further in this report because covered fish species are not affected.

2.9. Dry Creek

Dry Creek is a seasonal non-fish tributary to McKay Creek at about RM 4.0. The primary function of the creek within the OID system is conveyance of Crooked River and Ochoco Creek water between the canals. Live flow in the creek occurs only during spring snowmelt. Water is diverted from the creek by OID and individual patrons at four locations. Since Dry Creek does not support fish, none of the OID or patron structures on the creek have fish passage facilities or screens.

2.10. McKay Creek

2.10.1. Potential Presence of Covered Species

McKay Creek is a tributary to the Crooked River at about RM 44.9. The lower 19 miles of the creek are considered potential steelhead trout spawning and rearing habitat. McKay Creek is used as one of the juvenile fish release points for re-initiating anadromous fish runs in the Upper Deschutes River basin, and will likely offer spawning, rearing and migratory habitats for steelhead trout and spring Chinook salmon. Bull trout are currently absent from McKay Creek, and cannot use the covered reach as spawning and rearing habitat due to naturally high summer water temperatures. Adult bull trout may forage temporarily upstream of Highway 97 in the Crooked River and perhaps within McKay Creek when conditions are favorable.

2.10.2. Jones Dam and Siphon

Fish Passage: Jones Dam and Siphon is located at RM 5.8 on McKay Creek. A concrete structure with check boards allows OID to divert McKay Creek flow into the Ochoco Main Canal. A ladder at the diversion constructed in 2011 enables upstream movement of fish when the check boards are in place. Fish movement is unimpeded when the check boards are out of the creek.

Screens: The headgate to the canal is screened to exclude fish (Figure 2-11). The screens were designed and built by ODFW in 2001 to comply with NMFS screen criteria under a maximum design flow of 40 cfs (ODFW 2012b). The screens include 8-inch vertical bar trash racks in front of three rows of five, nearly 2-foot x 4-foot screen panels consisting of stainless steel 3/32-inch perforated plates. The maximum screen area is 114 feet^2. At the maximum 6-foot screen depth, the normal design approach velocity at 40 cfs would be 0.35 fps. The screen panels are mechanically cleaned with roller wiper assembly of screen brushes.

Figure 2-11. Fish exclusionary screens in the Ochoco Main Canal at Jones Siphon crossing.

2.10.3. Reynolds Siphon

Reynolds Siphon conveys water in the Crooked River Distribution Canal beneath McKay Creek at RM 3.2. OID can spill water from the canal into the creek at this location, but there is currently no structure in place to withdraw water from the creek. Development and operation of a diversion structure at this point is a covered activity to allow for the possibility it may be needed in the future. The siphon does not currently impede fish movement or present a risk of entrainment.

2.10.4. Cook Inverted Weir

Fish Passage: Cook Inverted Weir is located at RM 1.3 on McKay Creek. It is similar in design and construction to the inverted weir at Ryegrass. A 36-inch diameter steel pipe is laid horizontal across the creek to serve as both a weir and an intake for up to 5 cfs. Water passing over the weir is drawn by gravity through the top. The weir has a single V-notch to concentrate low flows and allow upstream and downstream fish movement. The bottom of the V-notch slot is positioned below the downstream water surface to eliminate the potential to dewater stream areas below the screens during extreme low flow conditions.

Screens: The horizontal surface of the Cook Inverted Weir functions as a fish screen for the intake. The structure has five 2-foot x 4-foot panels, with 0.07-inch (0.175 cm) profile bar screen material positioned perpendicular to flow. The screen panels have 16 percent gradients with a head differential of approximately 0.26 feet across the screen.

The USGS evaluated the weir and found the screen had approach velocities ranging from 0.10 to 0.16 fps, and average sweeping velocities of 2.3 to 4.7 fps, within the design diversion range of the weir and the range of streamflows observed during the 2004 and 2005 irrigation seasons (Rose et al. 2005). The mean sweeping velocities were found to be inversely related to the screen:weir ratio. The high screen: weir ratio of 41 percent for the Cook Inverted Weir had relative low mean sweeping velocities.

Based on video surveillance of fish contacts with the screen surface, the USGS calculated the effects of hydraulic and biological variables on the level of screen contact rates for the horizontal plate, inverted weir design as shown in Equation 1 above (Section 2.7.6 *Ryegrass Diversion*). As a result of the research, Rose et al. (2005) recommended 2.8 to 4.0 inches of water over the screen surfaces to minimize fish abrasion. At Cook, measured water depths over the screens averaged between 1.6 and 4.7 inches, which would provide a screen contact rate between 0 and 82 percent. Water depths were often shallower than average rates, leaving little water for fish passage at times.

Regardless, Rose et al. (2005) found the 24-hour survival rate for redband trout passing over the weir was over 99 percent, and the incidence of injuries was low. Up to 18 percent of fry and older fish passing over the weir received non-lethal injuries, but there were no statistically significant differences in the rates of injury between control fish (those passing over the weir when the screens were covered) and treatment fish (those with the potential to physically encounter the screens). Rose et al. (2005) concluded the inverted weir screens are safe and effective for salmonid fishes within the design range of diversions and the observed ranges of stream flow at the site.

Rose et al. (2005) noted that manual cleaning at intervals of 1 to 6 days was necessary to keep the screens free of debris. According to the authors, the inverted weir screens accumulated debris at about 5 percent of the screen area per day. The OID ditch riders clean the screens daily during the irrigation season. NFMS found the self-cleaning ability of a horizontal screen is enhanced when the ratio of sweeping velocity and approach velocity exceeds 20:1 (NFMS 2011). The sweeping to approach velocity ratio at Cook ranged between 23:1 and 29:1 exceeding the NMFS guidelines for self-cleaning of floating debris past the screens. Attached algae and periphyton continue to require daily physical cleaning.

2.10.5. Pine Products Siphon

Pine Products Siphon carries the Ryegrass Canal beneath McKay Creek at RM 1.0. OID can spill water into the creek at this location, but there is no structure to withdraw water from the creek. Development and operation of a diversion structure at this point is a covered activity to allow for the possibility one may be needed in the future. The siphon does not impede upstream or downstream fish passage or present a risk of entrainment.

2.10.6. Smith Inverted Weir

Fish Passage: Smith Inverted Weir diverts up to 4 cfs at RM 0.6 on McKay Creek for distribution to OID patrons in the surrounding area. The diversion is similar in design and construction to other OID inverted weirs. A horizontal steel pipe bedded in concrete diverts water from the creek (Figure 2-12). A single V-notch in the weir allows upstream and downstream fish movement. The bottom of the V-notch slot is positioned 0.8 foot above the downstream water to facilitate upstream fish passage and to eliminate the potential to dewater stream areas below the screens during extreme low flow conditions.

Screens: The horizontal surface of the Smith Inverted Weir functions as a fish screen. The structure has three 2-foot x 4-foot panels, with 0.07-inch (0.175 cm) profile bar screen material positioned perpendicular to flow. The screen panels have 17 percent gradients, with a head differential of approximately 0.82 feet across the screen.

The USGS evaluated the weir and found the screen had average sweeping velocities of 3.2 to 4.7 fps, within the design diversion range of the weir and the range of streamflows observed during the 2004 and 2005 irrigation seasons (Rose et al. 2005). The mean sweeping velocities were found to be inversely related to the screen : weir ratio and directly related to stream flow. The low screen : weir ratio of 23 percent for the Smith Inverted Weir had relative high mean sweeping velocities. Approach velocities were not measured in the field, but can be calculated based on the maximum withdrawal rate divided by the effective screen area. The design capacity of 4 cfs for the diversion results in an average approach velocity over three screens of 0.21 fps.

Based on video surveillance of fish contacts with the screen surface, the USGS calculated the effects of hydraulic and biological variables on the level of screen contact rates for the horizontal plate, inverted weir design as shown in Equation 1 above (Section 2.7.6 *Ryegrass Diversion*). As a result of the research, Rose et al. (2005) recommended 2.8 to 4.0 inches of water over the screen surfaces to minimize fish abrasion. At Smith, measured water depths over the screens averaged between 2.0 and 4.7 inches, which would provide a screen contact rate between 0 and 70 percent. Water depths were often shallower than average rates, leaving little water for fish passage at times.

Regardless, Rose et al. (2005) found the survival rate for redband trout passing over the weir was over 99 percent, and the incidence of injuries was low. Up to 85 percent of adult test fish received non-lethal injuries, but there were no statistically significant differences in the rates of injury between control fish (those passing over the weir when the screens were covered) and treatment fish (those with the potential to physically encounter the screens). Rose et al. (2005) concluded the inverted weir screens are safe and effective for salmonid fishes within the design range of diversions and the observed ranges of stream flow at the site.

Rose et al. (2005) noted that manual cleaning at intervals of 1 to 6 days was necessary to keep the screens free of debris. According to the authors, the inverted weir screens accumulated debris at about 5 percent of the screen area per day. The OID ditch riders clean the screens daily during the irrigation season. NFMS found the self-cleaning ability of a horizontal screen is enhanced when the ratio of sweeping velocity and approach velocity exceeds 20:1 (NFMS 2011). The sweeping to approach velocity ratio at Smith ranged between 4:1 and 6:1 at the maximum design capacity of the diversion. These levels are below the NMFS guidelines for self-cleaning of floating debris past the screens. Attached algae, periphyton, and stream debris continue to require daily physical cleaning. A withdrawal rate at the Smith diversion of 4.8 cfs or less would comply with NMFS most recent approach velocity criteria of 0.25 fps for horizontal flat plate screens on inverted weirs (NMFS 2011).

Figure 2-12. Smith Inverted Weir and horizontal flat plate fish screens in McKay Creek.

2.11. Lytle Creek

Lytle Creek is a tributary to the Crooked River at RM 41.0, downstream of McKay Creek. The lower 1.3 miles of Lytle Creek are merged with OID's Ryegrass Canal into a man-made ditch. The creek is generally dry above the OID boundary, but within the district it flows year round. The majority of flow is OID operational spill and return water during the irrigation season, but a small amount of live flow emerges from OID's D7 drain a short distance above Highway 26 throughout the year. The primary function of the creek within the OID system is conveyance of Crooked River and Ochoco Creek water between the canals. Water is diverted by OID and individual patrons at 11 locations above RM 0.5, including the portion of creek channel shared by the Ryegrass Canal. Typically, these withdrawals use stop-log structures to divert flows. Since Lytle Creek currently does not support covered fish above RM 0.5, none of the OID or patron structures has fish passage facilities or screens. If re-introduced covered fish find their way from the Crooked River into the mouth of Lytle Creek in the future, they could access the lowermost 0.5 mile of channelized stream year-round, but movement upstream of that point would be impeded during the irrigation season by at least some of the diversion structures maintained by patrons. Fish presence above RM 0.5 during the irrigation season would also be complicated since fish could move into the Ryegrass Canal and a number of the patron canals that carry water diverted from Lytle Creek. Outside the irrigation season, diversion structures would not be in place and fish could potentially move as far upstream as the Highway 26 crossing, although flows in the creek are considerably lower after operational spills and return flows cease for the year.

3.0 Conclusions

Current fish passage and fish screen conditions at 141 surface water points of diversion with respect to their adequacy to protect fish species covered under the DBHCP were evaluated in this study. Points of diversion with a potential to interact with covered fish species include those diversions in Whychus Creek (TSID) and the Crooked River system (City of Prineville, NUID, and OID). All other diversions are located upstream of potential distributions of covered fish species.

Diversion structures or screens requiring further evaluation under subsequent phases of this study include:

1) Unscreened OID Patron Pumps in the Crooked River (OID #s 3-36).
2) City of Prineville, non-compliant screen at Crooked River pump diversion.
3) OID non-compliant screen at the Breese Diversion on Ochoco Creek.
4) OID patron pumps on Ochoco Creek (OID #s 6-38).
5) NUID low berm at the intake on the Crooked River.

All other diversions in the Whychus and Crooked River systems are either appropriately situated and screened for effective fish passage or they are located upstream of areas accessible to covered fish species.

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Appendix A

Breese Diversion Hydraulic Evaluation

Breese Diversion Hydraulic Evaluation

I) – Introduction

There are no files on record with Federal or State resource agencies or with Ochoco Irrigation District concerning compliance of the Breese Diversion screens with fish passage criteria. As a consequence, cursory hydraulic measurements were collected from the screens during a DBHCP site visit on July 11, 2012. This appendix includes the measurements and a brief evaluation of the current screen conditions with respect to the federal criteria.

II) – Federal (NMFS) Fish Passage Criteria for Anadromous Species

The National Marine Fisheries Service (NMFS) recently updated their fish passage facility design criteria and guidelines to minimize adverse impacts to anadromous fish migrations as of July 2011 (NMFS 2011). Two portions of the NMFS document influence the hydraulic review of the Breese Diversion screens: 1) a discussion of existing screens, in place prior to implementation of these criteria (§11.4 of the 2011 criteria), and 2) horizontal screens evaluated as experimental technology (§ 11.6.1.7 of the 2011 criteria).

Existing Screens

If a fish screen was constructed prior the establishment of these criteria, but constructed to NMFS criteria established August 21, 1989, or later, approval of these screens may be considered providing that all six of the following conditions are met:

(1) The entire screen facility must function as designed.

(2) The entire screen facility has been maintained and is in good working condition.

(3) When the screen material wears out, it must be replaced with screen material meeting the current criterion stated in this document. To comply with this condition, structural modifications may be required to retrofit an existing facility with new screen material.

(4) No mortality, injury, entrainment, impingement, migrational delay, or other harm to anadromous fish has been noted that is being caused by the facility.

(5) No emergent fry are likely to be located in the vicinity of the screen, as agreed to by NMFS biologists familiar with the site.

(6) When biological uncertainty exists, access to the diversion site by NMFS is permitted by the diverter for verification of the above criteria.

Horizontal Screens

NMFS views horizontal screens as experimental technology, because they operate fundamentally different than conventional vertically oriented screens. This fundamental difference relates to fish safety when water levels on horizontal screens drop. There is likelihood fish could become injured on the screened surface during such events.

NMFS considers horizontal screens as biologically equivalent to conventional screens if the following criteria and guidelines, among others, are achieved for the entire juvenile outmigration season in design and operation:

Site Limitation:

- Horizontal screens must not be installed spanning the entire width of stream.
- Upstream fish passage must not be impeded by installation of a horizontal screen.
- Horizontal screens must be installed such that the approaching conveyance channel is completely parallel and in line with the screen channel so uniform flow conditions exist at the upstream edge of the screen. A straight channel should exist for at least twenty feet upstream of the leading edge of the horizontal screen, or up to two screen channel lengths if warranted by approach flow conditions in the conveyance channel.

Bypass Flow Depth:

- The bypass flow must pass over the downstream end of the screen at a minimum depth of one foot.

Bypass Flow Amount:

Bypass flow is used for transporting fish and debris across the plane of the screen and through the bypass conveyance back to the stream.

- For diversion rates less than 100 cfs, about 15 percent of the total diverted flow should be used as bypass flow for horizontal screens. Small horizontal screens may require up to 50 percent of the total diverted flow as bypass flow.

Diversion Shut-off:

The horizontal screen design must include an automated means to shut off the diversion flow, or a means to route all diverted flow back to the originating stream.

Sediment Removal:

The horizontal screen design must include means to simply and directly remove sediment accumulations under the screen, without compromising the integrity of the screen while water is being diverted.

Screen Approach Velocity:

Screen approach velocity is calculated by dividing the maximum flow rate by the effective screen area.

- The approach velocity must be less than 0.25 fps and uniform over the entire screen surface area.

Screen Sweeping Velocity:

For horizontal screens, sweeping velocity must be maintained or gradually increase for the entire length of screen. Higher sweeping velocities may be required to achieve reliable debris removal and to keep sediment mobilized.

- Sweeping velocity should never be less than 2.5 fps.

Screen Cleaning:

- For passive horizontal screens, approach velocity and sweeping velocity must work in tandem to allow self-cleaning of the entire screen face and to provide good bypass conditions.

NMFS cites recent prototype development that demonstrated self-cleaning of a horizontal screen is consistently achieved when the ratio of sweeping velocity and approach velocity exceeds 20:1, and approach velocities are less than 0.1 fps.

Inspection, Maintenance and Monitoring:

- Daily inspection and maintenance must occur of the screen and bypass to maintain operations consistent with these criteria.
- Post construction monitoring of the facility must occur for at least the first year of operation.
- Monitoring must occur whenever water is diverted, and include an inspection log (in table form) of date and time, water depth at the bypass, debris present on screen (including any sediment retained in the screen openings), fish observed over the screen surface, operational adjustments made, maintenance performed and the observer's name.
- A copy of the inspection log must be provided annually to the NMFS design reviewer, who will review operations and make recommendations for the next year of operation.

Screen Material

Circular Screen Openings:

- Circular screen face openings must not exceed 3/32 inch in diameter.
- Perforated plate must be smooth to the touch with openings punched through in the direction of approaching flow.

Slotted or Rectangular Screen Openings:

- Slotted or rectangular screen face openings must not exceed 1.75 mm (approximately 1/16 inch) in the narrow direction.

Square Screen Openings:

- Square screen face openings must not exceed 3/32 inch on a side.

Material:

- The screen material must be corrosion resistant and sufficiently durable to maintain a smooth uniform surface with long-term use.

Open Area:

- The percent open area for any screen material must be at least 27%.

Other Components:

Other components of the screen facility (such as seals) must not include gaps greater than the maximum screen opening defined above.

III) – Breese Diversion Screen Design

Intake Description

Breese Diversion is an inverted weir at approximately RM 7.7 on Ochoco Creek constructed with of a perforated 36-inch diameter steel pipe laid horizontal across the creek and bedded in concrete. The pipe serves as both a weir and an intake, as water is drawn by gravity through openings in the top covered by perforated screens. Water in the pipe continues by gravity flow to both streambanks, where it is pumped into OID canals. Each of the two pumps has a capacity of 5 cfs. The average operational withdrawal rate is typically half the rated capacity. The weir has a 2.5-foot deep V-notch to concentrate low flows and facilitate upstream and downstream fish movement. Since the V-notch is lower than the perforated screens, it also functions as an automatic diversion cutoff during low stream flows to ensure the weir cannot dewater the creek.

The horizontal surface of the inverted weir at the Breese diversion serves as a fish screen. The intake screens consist of eight 2 foot x 4 foot panels covered with 3/32-inch perforated screen material. The total screen surface area is 64 feet^2 with an effective surface area of 51.2 feet^2 allowing for structural members beneath the screen where water doesn't enter the screens. The screen surfaces are curved slightly in the downstream direction. The screen panels have 17 percent gradient with a head differential of approximately 0.5 feet across the screen face. Hydraulic measurements of the screen performance collected during a DBHCP site visit on July 11, 2012 are summarized in the following section.

Hydraulic Measurements

Hydraulic measurements occurred at the Breese Diversion site (Figure A-1) during the morning hours of July 11, 2012. The stream discharge in Ochoco Creek at a transect located approximately 10 feet upstream of the diversion at the time of the diversion assessment was 15.9 cfs. A cross-section of the discharge measurement site is shown in Figure A-2. Sweeping velocities across the intake screen panels were taken with a Swoffer velocity meter [R2 meter #3602] with a large propeller (#17B), under calibration #127, at the left, center, and right side at the upstream and downstream edges of each screen panel. Approach velocities were not measured in the field, but calculated based on the maximum withdrawal capacity and the withdrawal rate during July 11 in relation to the effective screen surface area. Water depths were measured along the screen face at the upper, middle, and lower edges of each screen. Hydraulic data measured at the Breese intake screens are shown in Table A-1.

Sweeping Velocity

The sweeping velocity (SV) across the upper edges of all eight screens was measured between 1.2 and 2.9 fps and averaged 2.0 ± 0.4 fps at a stream discharge of 15.9 cfs in Ochoco Creek. Sweeping velocities decreased approximately 40 percent across the screen face, with SVs along the downstream edge of the screens ranging between 0.0 and 2.8 cfs while averaging 1.2 ± 0.8 cfs. For inverted weir structures, Rose et al. (2005) found sweeping velocities directly related to stream discharge and inversely related to the screen-to-weir ratio (linear length of the screens/linear length of the instream portion of the weir). For Breese, the screen-to-weir ratio was 55 percent. This ratio was nearly identical to the measured screen-to-weir ratio for the Ryegrass diversion further downstream in Ochoco Creek. Relatively high screen-to-weir ratios like for the Breese and Ryegrass diversions generally equates to lower SVs than for low screen-to-weir ratios like the Cook and Smith diversions in McKay Creek.

Approach Velocity

Screen approach velocities (AV) (velocities perpendicular to the screens) were not measured in the field, but calculated based on 10 cfs maximum design withdrawal capacity (Q_i) and a 4.25 cfs withdrawal rate during July 11 (Q_a) in relation to an effective screen surface area of 51.2 feet^2. The associated approach velocities for the Breese intake screens are shown in the equations below:

Eqn. 1. $\mathbf{AV_i = Q_i / SA_e}$

Where:
- AV_i = Instantaneous maximum approach velocity (0.20 fps)
- Q_i = Instantaneous maximum withdrawal (10 cfs)
- SA_e = Effective screen surface area (51.2 feet^2)

Eqn. 2. $\mathbf{AV_a = Q_a / SA_e}$

Where:
- AV_a = Average approach velocity (0.08 fps) July 11, 2012
- Q_i = Average Breese withdrawal (4.25 cfs) July 11, 2012
- SA_e = Effective screen surface area (51.2 feet^2)

Figure A-1. Breese Diversion in Ochoco Creek (RM 7.7) at 15.9 cfs.

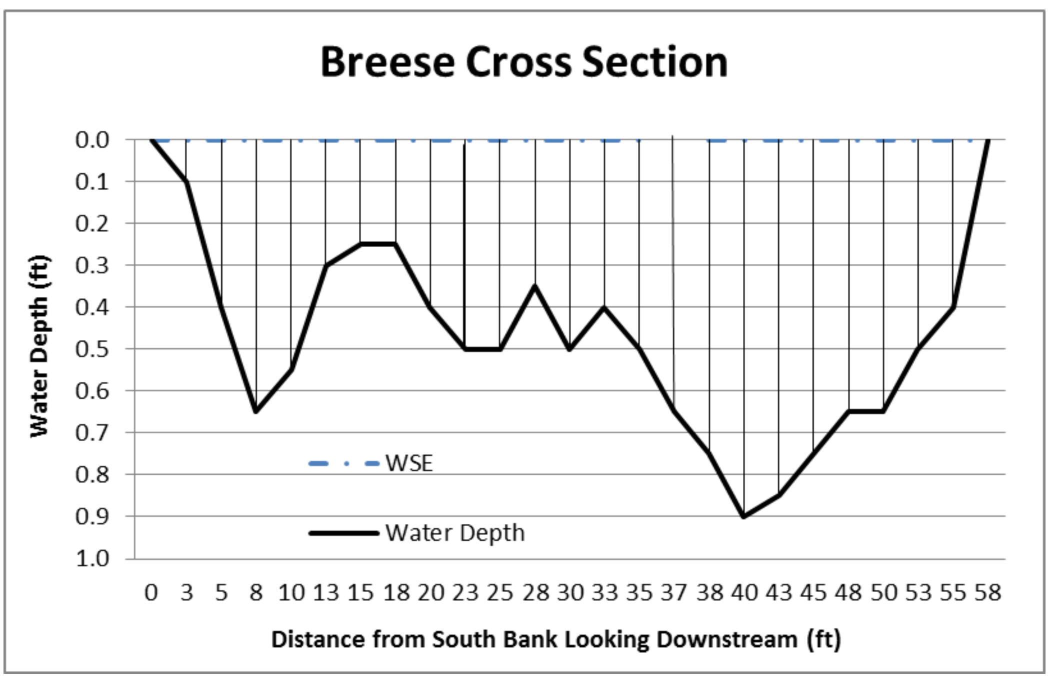

Figure A-2. Cross section of Ochoco Creek 10 feet upstream of Breese Diversion.

Table A-1. Hydraulic measurements at Breese Diversion in Ochoco Creek, July 11, 2012.

Screen [1/]	Location [2/]	Sweep Velocity (fps)		Water Depth (inches)			Self-Cleaning Ratio[3/]		Comment
		Upstream	Downstream	Upstream	Middle	Downstream	Upstream	Downstream	
1	L	1.61	1.80				20	23	
	M	1.60	0.27	1.75	0.50	0.25	20	3	
	R	2.17	0.61				27	8	
2	L	2.30	0.00	1.75	0.50	0.00	29	0	Dry on downstream edge.
	M	1.20	.027				15	3	Damaged; screen partially separated from concrete and bent.
	R	1,68	0.00				21	0	Dry on downstream edge.
3	L	2.33	1.25				29	16	
	M	2,24	1.25	1.75	0.50	0.75	28	16	
	R	2.17	1.26				27	16	
4	L	1.65	1.80				21	23	
	M	2.60	2.84	1.75	0.50	0.75	33	36	
	R	2.87	0.69				36	9	
5	L	1.70	2.60				21	33	
	M	2.12	1.50	1.75	0.50	0.75	27	19	

Screen 1/	Location 2/	Sweep Velocity (fps)		Water Depth (inches)			Self-Cleaning Ratio 3/		Comment
		Upstream	Downstream	Upstream	Middle	Downstream	Upstream	Downstream	
	R	2.27	1.26				28	16	
6	L	1.93	0.54				24	7	
	M	2.38	1.60	1.75	0.50	0.25	30	20	
	R	2.08	1.77				26	22	
7	L	1.66	0.00				21	0	Dry on downstream edge;
	M	1.96	0.93	2.00	0.50	0.25	25	12	Debris altered flow-
	R	2.14	2.36				27	30	patterns
8	L	1.27	0.37				16	5	
	M	1.95	1.68	1.75	0.50	0.13	24	21	
	R	1.71	1.39				21	17	
STATS	**Min**	**1.20**	**0.00**	**1.75**	**0.50**	**0.00**	**15**	**0**	
	Mean	**1.98**	**1.17**	**1.78**	**0.50**	**0.35**	**25**	**15**	
	Max	**2.87**	**2.84**	**2.00**	**0.50**	**0.75**	**36**	**36**	
	St. Dev.	**0.40**	**0.82**	**0.09**	**0.00**	**0.32**	**5**	**10**	

1) Screen order from south bank to north bank.

2) Location code: L – Left; M – Middle; R – Right

3) Self-cleaning ratio is SV/AV during the day of the measurements (AV = 0.08).

Water Depth

Water depths over the upper, middle, and lower portions of the Breese Diversion screens measured during a discharge of 15.9 cfs in Ochoco Creek are shown in Table A-1. The mean depth of water from the three locations over each screen ranged from 0.75 to 1.00 inch. Water was deeper at the upstream end (1.75 to 2.00 inch) compared to the downstream end (0.00 to 0.75 inch). On average, an 80 percent loss of water depth across the screen was recorded. The depths at the leading edge and middle parts of the screens were relatively uniform, but variable and sometimes dry over the downstream edge. Two screens supported dewatered screen sections. The second screen panel from the south bank was damaged. The screen was partially separated from the pipe and bent upward, exposing the nearshore corner edge of the screen. The seventh panel from the south bank had sufficient debris on the surface to modify flow patterns in a manner that left the trailing edge of the right side dry. Based on the water depths measured during the survey and the Rose et al. (2005) screen contact equation (Figure A-3) an estimated 70 to 100 percent of the fish passing the diversion would come in contact with the surface of the screens.

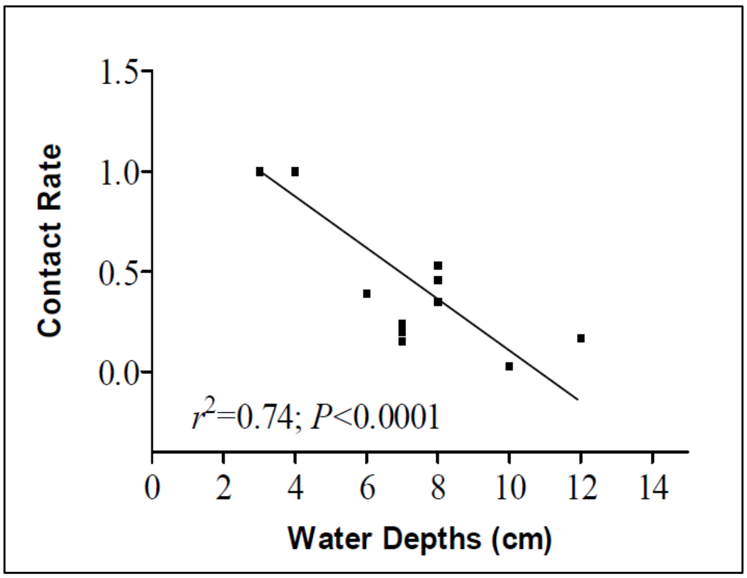

Figure A-3. Relationship between the rate of observed fish screen contacts (SC) and water depths (Z) over horizontal flat-plate screens. SC = 1.354 - 0.131(Z)

Source: Rose et al. (2005)

Cleaning

The OID ditch riders clean the Breese Diversion screens daily during the irrigation season. According to Rose et al. (2005), the inverted weir screen designs accumulated debris at about 5 percent of the screen area per day (Figure A-4). NFMS found the self-cleaning ability of passive horizontal screens is consistently achieved when the ratio of sweeping velocity and approach velocity exceeds 20:1 (NFMS 2011).

The sweeping to approach velocity ratio at Breese during stream discharge of 15.9 cfs ranged between 15:1 and 36:1 and averaged 25:1 ± 5:1 on the upstream edge of the screen, and ranged between 0:1 and 36:1 and averaged 15:1 ± 10:1 on the downstream edge of the screen.

Figure A-4. One-day accumulation of algal growth on Breese flat-plate screen surface.

IV) – Discussion

Hydraulic Measurements

Sweeping Velocity

Rose et al. (2005) documents increased rates of fish injury with screen contact and impingement when sweeping velocities were less than 4 fps. NMFS guidelines suggest the SV should not be less than 2.5 fps. The maximum SVs across the Breese screens were 3 fps and averaged near 2 fps at the upstream edge of the screens. Following a 40 percent loss across the screens, SVs averaged approximately 1.2 fps. The decreased sweeping velocities across the screen are inconsistent with NMFS 2011 criteria for new horizontal flat-plate screens.

Approach Velocity

The instantaneous maximum approach velocity for the design capacity of the Breese Diversion of 0.20 fps falls within the NMFS 2011 criteria for new horizontal flat-plate screens.

Water Depth

Water depths over the screens can be shallow at times leaving little water for fish passage. Some of the screen areas were dewatered (#2 damaged; #7 debris) potentially exposing the fish to direct contact with the screens. Screen contact can lead to abrasion and descaling injuries to the fish. Although Rose et al. (2005) observed a high incidence of fish-screen interactions with other inverted weir diversions in the region, they noted little mortality (>1%) in a 24-hour period. Since abrasion and descaling-related injuries can lead to delayed mortalities, minimizing screen contact remains a desirable objective. Rose et al. (2005) recommended water depths of 2.8 to 4.0 inches of water over the inverted weir screen surfaces to minimize fish abrasion. The NMFS bypass depth criteria requires 12.0 inches of water over the downstream edge of horizontal flat-plate screens. The maximum water depths at Breese on July 11, 2012 were 2.0 inches at the upstream edge and less than 1.0, and sometimes dry, at the downstream edge.

Cleaning

The initial sweep to approach velocity at the leading edge of the screens offered a good level of self-cleaning of floating debris. However, at the downstream trailing edge of the screens the ratio frequently fell below the NMFS guidelines allowing the potential for debris to accumulate. Attached algae, periphyton and stream debris continue to require daily physical cleaning.

Comparison to Federal Screen Criteria

A comparison of the Breese Diversion screen conditions to the NMFS screening criteria and guidelines for existing and for horizontal screens is provided in the sections below on a point-by-point basis.

Existing Screens

A comparison of existing conditions found at the Breese Diversion site with the following six categories required for approval of intakes installed prior to the updated NMFS criteria (NMFS 2011) is included in Table -2, below:

Table A-2. Comparison of Breese Diversion conditions with NMFS criteria for existing screen approval.

Category	Condition of Breese Diversion
(1) The entire screen facility must function as designed.	No, one bent screen panel with dewatered screen surface.
(2) The entire screen facility has been maintained and is in good working condition.	Ongoing maintenance, but one bent screen with dewatered screen surface
(3) When the screen material wears out, it must be replaced with screen material meeting the current criterion stated in this document. To comply with this condition, structural modifications may be required to retrofit an existing facility with new screen material.	With the exception of the bent screen noted above, the perforated screen material appears in good working condition. The screen mesh size is 3/16-inch openings for seven of the screen panels and 3/32-inch for the eighth panel.
(4) No mortality, injury, entrainment, impingement, migrational delay, or other harm to anadromous fish has been noted that is being caused by the facility.	None noted during the July 11, 2012 survey.
(5) No emergent fry are likely to be located in the vicinity of the screen, as agreed to by NMFS biologists familiar with the site.	Spawning gravels are present in Ochoco Creek upstream of the Breese Diversion site. There is a potential for the presence of emergent fry following re-introduction of covered fish species.
(6) When biological uncertainty exists, access to the diversion site by NMFS is permitted by the diverter for verification of the above criteria.	Access is available.

Horizontal Screens

A comparison of existing conditions found at the Breese Diversion site with the following eleven categories required for approval of new intakes installed after the updated NMFS criteria (NMFS 2011) is included in Table A-3, below:

Table A-3. Comparison of Breese Diversion conditions with NMFS criteria for horizontal screen approval.

Category	Criteria	Existing Condition
Site Limitation	Horizontal screens must not be installed spanning the entire width of stream.	V-Notch precludes full spanning of the stream.
	Upstream fish passage must not be impeded by installation of a horizontal screen.	V-Notch facilitates upstream fish passage.
	Horizontal screens must be installed such that the approaching conveyance channel is completely parallel and in line with the screen channel.	Upstream channel is parallel and in line with the screens.
Bypass Flow Depth	The bypass flow must pass over the downstream end of the screen at a minimum depth of 12 inches. USGS established depth of 4 inches offered zero contact with the screen face.	Maximum water depths at the downstream end of the Breese screens were less than 1 inch at ~ 15.9 cfs of stream flow.
Bypass Flow Amount	Small horizontal screens may require up to 50% of the total diverted flow as bypass flow.	Bypass flow on July 11th was 73% of the total streamflow and a factor of 2.7 x the total diverted flow.
Diversion Shut-off	The horizontal screen design must include an automated means to shut off the diversion flow, or a means to route all diverted flow back to the originating stream.	V-Notch provided automated diversion shut-off.
Sediment Removal	The horizontal screen design must include means to simply and directly remove sediment accumulations under the screen, without compromising the integrity of the screen while water is being diverted.	Not reviewed during site visit.

Category	Criteria	Existing Condition
Screen Approach Velocity [maximum flow rate/ effective screen area]	The approach velocity must be less than 0.25 fps and uniform over the entire screen surface area.	Approach velocity was not measured in the field, but calculated from the maximum design capacity AV = (10 cfs/51.2 ft^2) = 0.20 fps. The mean Approach Velocity on July 11 was calculated as (4.25/51.2 = 0.08 fps).
Screen Sweeping Velocity	Sweeping velocity must be maintained or gradually increase for the entire length of screen.	Sweeping velocities at Breese were lower at the downstream edge of the screens than the leading edge. At a stream discharge of 15.9 cfs, the screens experienced a 40 % loss of sweeping velocity across the screen face.
	Sweeping velocity should never be less than 2.5 fps.	Sweeping velocities at Breese with a stream discharge of 15.9 cfs averaged 2.0 fps and ranged between 0.0 and 3.0 fps.
Screen Cleaning	For passive horizontal screens, approach velocity and sweeping velocity must work in tandem to allow self-cleaning of the entire screen face and to provide good bypass conditions. Self-cleaning is consistently achieved when the ratio of sweeping velocity and approach velocity exceeds 20:1.	The ratio of SV:AV at the Breese Diversion during stream discharge of 15.9 cfs ranged between 15:1 and 36:1 on the upstream edge of the screen, and ranged between 0:1 and 36:1 on the downstream edge of the screen.
Inspection, Maintenance and Monitoring	Daily inspection and maintenance must occur of the screen and bypass to maintain operations consistent with these criteria.	Ditch Riders provide daily inspections during the irrigation season.

Category	Criteria	Existing Condition
	Post construction monitoring of the facility must occur for at least the first year of operation.	The Breese Diversion was constructed in 1998. No monitoring records are available.
	Monitoring must occur whenever water is diverted, and include an inspection log (in table form) of date and time, water depth at the bypass, debris present on screen (including any sediment retained in the screen openings), fish observed over the screen surface, operational adjustments made, maintenance performed and the observer's name.	No monitoring records are available.
	A copy of the inspection log must be provided annually to the NMFS design reviewer, who will review operations and make recommendations for the next year of operation.	No inspection logs are available.
Screen Material -Circular Screen Openings	Circular screen face openings must not exceed 3/32 inch in diameter.	The screen mesh size is 3/16-inch openings for seven of the screen panels and 3/32-inch for the eighth panel.
	Perforated plate must be smooth to the touch with openings punched through in the direction of approaching flow.	Perforated plate is smooth and punched as indicated.
	The screen material must be corrosion resistant and sufficiently durable to maintain a smooth uniform surface with long-term use.	Screen material has been in place for fourteen years and is durable.
	The percent open area for any screen material must be at least 27%.	Open area of screen material exceeds 27%.
Other Components	Other components of the screen facility (such as seals) must not include gaps greater than the maximum screen opening defined above.	Seals were not evaluated during the July 11 site visit. Damaged screen panel #2 was pulled away from the base.

V) – Conclusions

The Breese Diversion was constructed and approved in accordance with available biological criteria existing in the late 1990s. Acceptance of ongoing operations falls under the existing screen criteria (§11.4 of the 2011 NMFS criteria). Other than the bent screen that requires repair, and the location of the intake near potential spawning and incubation habitats, the screens comply with the categorical approvals NMFS established for existing screens.

A comparison was also performed to assess how the current screen conditions would perform against the criteria for construction of new horizontal flat-plate screens. NMFS views the horizontal screens as experimental technology, because they operate fundamentally different than conventional vertically oriented screens. The Breese screens complied with the categories for: 1) Site Limitations (V-notch; fish passage; channel approach); 2) Bypass Flow Amount (more than 50% of diverted water); 3) Diversion Shut-off (V-notch); 4) Approach Velocity (maximum instantaneous design capacity < 0.25 fps); and 5) Screen Materials (smooth, corrosion resistant, durable surfaces, % open areas > 27%;. The Breese intake screens would not likely comply with: 1) sweeping velocity criteria (> 2.5 fps, and steady velocities across the screen face); 2) Self-cleaning screen guidelines of sweeping to approach velocity ratio of > 20:1; 3) Screen Materials (circular openings < 3/32 inch) and 4) Monitoring requirements. It is unknown if the operation of the Breese Diversion would comply with the sediment removal requirements.